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CONTENTS

Lime Application to a Soft-water, Unproductive Lake in Northern Michigan — *Thomas F. Waters and Robert C. Ball* 385

Analysis of Variation among Participants in Pheasant Cock-crowing Censuses — *Samuel M. Carney and George A. Petrides* 392

Movements of White-tailed Deer Tagged in Minnesota — *J. C. Carlsen and Robert E. Farmes* 397

Reclamation of Coal Strip-mined Lands with Reference to Wildlife Plantings — *Charles V. Riley* 402

The Smallmouth Bass, *Micropterus dolomieui*, in Warm-water Ponds — *George W. Bennett and William F. Childers* 414

Food Habits of the Coyote in Missouri — *Leroy J. Korschgen* 424

Mandibular Dentition as an Age Indicator in Rocky Mountain Elk — *Don C. Quimby and J. E. Gaab* 435

The Wildlife Society: Nominations for Offices, 1958–59 — 451

Briefer Articles

A Better Snowshoe Hare Live Trap — *Wilbur L. Libby* 452

A Device for Holding Rabbits during X-ray Photography — *R. L. Edgar* 453

Results of a Woodchuck Control Experiment — *Antoon de Vos and Howard A. Merrill* 454

An Automatic Nest-trap for Waterfowl — *Milton W. Weller* 456

Avian Recoveries from Mutilating Accidents to Both Legs — *W. G. Leitch and Robert A. McCabe* 458

Black Locust for Quail in Massachusetts — *Thomas H. Ripley, Russell A. Cookingham, and Robert P. Corrinet* 459

A Calculator for Handling Large Series of Aged-brood Data — *Charles H. Schroeder* 459

Effectiveness of Two Flushing Devices Used in Hay Mowing — *Gordon L. Zorb* 461

Use of Prolactin to Induce Broodiness in Two Wild Turkeys — *Charles G. Crispens, Jr.* 462

The Problem of Changing Beliefs and Attitudes — *H. G. Lumsden* 463

The Use of Dewatered Land in Southeastern Waterfowl Management — *Lawrence S. Givens and Thomas Z. Atkeson* 465

Effects of Predator Guards on Wood Duck Box Usage — *John M. Cronan* 468

Leucocytozoon bonasae Clarke in Michigan Sharp-tailed Grouse — *Archibald B. Cowan and Tony J. Peterle* 469

Some Effects of a Severe Windstorm on Coot Nests — *Stanley W. Harris and William H. Marshall* 471

Editorial Note — 473

Reviews — 474

Index to Volume 21 — 479

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THE JOURNAL OF WILDLIFE MANAGEMENT

VOLUME 21 OCTOBER 1957 NUMBER 4

LIME APPLICATION TO A SOFT-WATER, UNPRODUCTIVE LAKE IN NORTHERN MICHIGAN

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In the Upper Peninsula of Michigan, as well as in other northern glaciated regions, there are many colored, very soft-water lakes. It is well known that this particular type of lake is relatively unproductive; a rough correlation between alkalinity and productivity can be inferred from the reports of Ball (1948), Moyle (1949), and others. From these observations the hypothesis follows that increasing the alkalinity through the application of liming compounds may increase productivity. Lime application has been used extensively in European carp ponds (Neess, 1949) and has been developed by soil scientists in terrestrial agriculture to extremely good advantage.

The development of a similar technique that would increase the productivity of the soft-water lakes in the Upper Peninsula of Michigan would be instrumental in enlarging the sport-fishery resources of this region. One of these lakes, Stoner Lake, in Alger and Delta counties, was the object of a biological survey conducted by the Michigan Department of Conservation in 1937. In an unpublished report of the survey (Roelofs, 1941), which described Stoner Lake as having an alkalinity of 6 p.p.m., largely a barren sand bottom, little vegetation, and a scarcity of fish-food organisms, it was suggested that an experimental program of lime application be conducted on Stoner Lake. This report is an account of the research upon Stoner Lake made by the Institute for Fisheries Research of the Michigan Department of Conservation in cooperation with Michigan State University, testing the feasibility of increasing productivity in a soft-water lake through the application of lime.

Acknowledgment is extended for administrative assistance to Peter I. Tack, for assistance with statistical treatment to Don W. Hayne, for assistance with chemical analyses to Paul H. Barrett, all from Michigan State University; and to Merle G. Galbraith and other personnel from the Institute for Fisheries Research for assistance with the lime application. The drawings were prepared by William L. Cristanelli. The project was a cooperative study as already mentioned, and was financed partially by a fellowship received from the National Science Foundation by the senior author.

METHODS

In 1943, three tons of hydrated lime (calcium hydroxide) were applied to Stoner Lake. This application was apparently too small, since no change in alkalinity of any significance was effected (E. W. Roelofs, pers. comm.).

In 1946, 20 tons of pebble-sized limestone (calcium carbonate) were applied to Stoner Lake. The limestone was distributed near the shore in shallow water over the barren sand bottom from a small boat. The alkalinity, which was 6 p.p.m. before the application, remained at the same concentration following the application; during the following year (1947), chemical analysis of the water showed the alkalinity to have remained at 6 p.p.m., there having been no increase in alkalinity effected by either application.

In Wisconsin, Hasler, Brynildson, and Helm (1951) showed an increase in the alkalinity of soft-water lakes through the addition of hydrated lime. Barrett (1951), following laboratory experiments involving the ap-

plication of calcium carbonate to beakers containing mud and water from Stoner Lake, suggested that the failure of the limestone to change the *p*H of the lake may have been due to the adsorption of calcium by the organic matter of the lake. He recommended that sufficient hydrated lime, which is more soluble than limestone, be applied to alkalinize the water and also to neutralize the top one centimeter of mud, and that sufficient limestone be applied for slow dissolution to offset further adsorption by the mud. On the basis of these recommendations and the area and volume data from Stoner Lake, the suggested applications were calculated to total 8.5 tons of hydrated lime and 2 tons of crushed limestone.

In 1952, a more intensive study was initiated on Stoner Lake, continuing through the four summers of 1952, 1953, 1954, and 1955. This report is concerned primarily with the results of this study.

The conditions in Stoner Lake were found in 1952 to be essentially the same as determined by the biological survey of 1937; alkalinity was about 6 p.p.m., the *p*H was slightly acid, and the water was colored; little aquatic vegetation was found. Stoner Lake is about three-fourths of a mile long, about one-fourth mile wide and has two depressions with a shallow area between; the two depressions, with a maximum depth of about 20 feet, have pulpy peat as the bottom material, while the shallower areas have largely a barren sand bottom. There was no bog formation around the shores. The surface area, from a map constructed in 1952, was determined to be about 90 acres. Stoner Lake was not observed to stratify thermally. The fish population was composed primarily of stunted yellow perch (*Perca flavescens*), ranging in size to about 5 inches and in age to 5 years; a smaller population of larger yellow perch, apparently cannibalistic, was also present; other species found were common white suckers (*Catostomus commersoni commersoni*), bluegills (*Lepomis m. macrochirus*), and mudminnows (*Umbra limi*).

The studies initiated in 1952 consisted of periodical sampling of chemical conditions relating to alkalinity, dissolved oxygen and carbon dioxide, *p*H, total hardness, and conductivity, and physical conditions of temperature, light penetration, and color. Net plankton samples were collected during the same periods by means of a Juday trap. These were taken at a depth of 3 feet from two sampling stations, one in each lake depression. The volume estimations of the samples were made by determination of the volume of the cells of the various species and cell counts.

Samples from the bottom fauna were collected periodically from two sampling stations, one in each depression, with an Ekman dredge; these samples were analyzed volumetrically by the water-displacement method. The collections of fish samples for growth-rate determination were made with gill nets, a bag seine, and by angling; these collections were made at irregular times without a formal program of sampling. The collection of stunted yellow perch was made primarily by angling during 1952, but it soon became apparent that this extremely large population of stunted fish represented the group of primary interest, and in subsequent years a bag seine was used to facilitate the collection of samples from this group.

Following initial chemical analyses of the lake water in the early summer of 1952, an application of 8.5 tons of hydrated lime and 2 tons of crushed limestone was made.[1] The materials were distributed from a small boat around the shoreline of the lake in shallow water over sand bottom.

It was apparent, following this 1952 application, that the rate of application was still too small, and another application, of 20 tons of hydrated lime,[1] was made in the early summer of 1953. This application was made in a manner similar to that employed in 1952.

CHEMICAL EFFECTS OF LIME APPLICATION

Fig. 1 shows the changes in alkalinity and *p*H, at a depth of 3 feet, for the four years of periodical sampling. Following the 1952 lime application, the alkalinity increased from approximately 6 p.p.m. to 9 p.p.m.

[1] The hydrated lime and limestone were obtained from Haviland Products Company, Grand Rapids, Michigan. Limited analyses (by the senior author) determined the hydrated lime to be approximately 99 per cent calcium hydroxide, $Ca(OH)_2$, and the limestone to be approximately 50 per cent $CaCO_3$ and 50 per cent $MgCO_3$ (as $CaCO_3$).

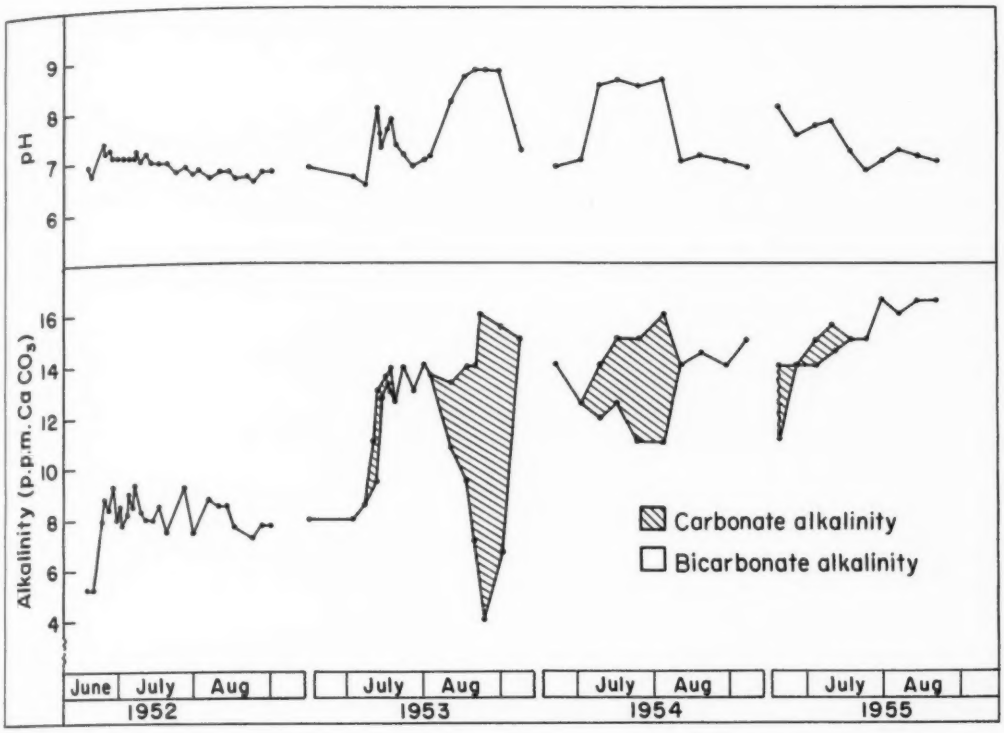


FIG. 1. Alkalinity and *p*H in Stoner Lake, 1952–55.

Since the theoretical increase, calculated from the materials applied and the volume of the lake, was about 15 p.p.m., the increase in alkalinity indicated an efficiency of about 20 per cent. Immediately following the application, the concentration of dissolved carbon dioxide decreased slightly, but no carbonate alkalinity appeared; the *p*H rose following the application, but descended again to near pre-application levels, due to the reaction of carbon dioxide with the calcium hydroxide.

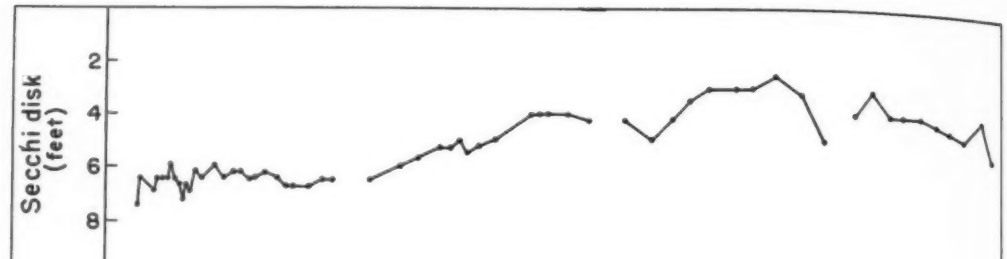
Following the 1953 application, the alkalinity increased from approximately 8 p.p.m. to 14 p.p.m., again indicating an efficiency of about 20 per cent; some carbonate alkalinity appeared with the corresponding loss of carbon dioxide. The *p*H rose following the application, but descended again to near pre-application levels. During the summers of 1953, 1954, and 1955, several plankton blooms occurred which had marked effects upon the *p*H and the form of alkalinity due to the extraction of carbon dioxide from the bicarbonates. These effects show (Fig. 1) the appearance of carbonate alkalinity and the corresponding rise of the *p*H at the times of plankton bloom. In each case, following the subsidence of the bloom, the alkalinity returned entirely to the bicarbonate form and the *p*H descended again to approximately neutral.

In addition to the data shown in Fig. 1, Stoner Lake was checked in the early spring of 1956 and again in the autumn of 1956, and the alkalinity was found upon each occasion to have remained at 15 p.p.m.

No direct effects of the lime applications upon the concentration of dissolved oxygen were observed. Total hardness and conductivity followed the same trends as total alkalinity. There were no changes in color attributable to the lime applications.

PLANKTON RESPONSE

Fig. 2 shows the average volume of net phytoplankton for the four years of intensive study; each point represents the average of four Juday plankton-trap samples, two samples having been taken from each



F . . 2. Secchi-disk readings and average volume of net phytoplankton in Stoner Lake, 1952–55.

of the two sampling stations. As further indications of plankton abundance, light-penetration data, as obtained with a Secchi disk, are included in Fig. 2.

During 1952, the standing crop of net phytoplankton was exceptionally low except for that on one sampling date when a temporary increase, due principally to *Dinobryon sertularia* Ehrenberg, occurred. Secchi-disk readings averaged about 6 feet, with no effects of the *Dinobryon* pulse observed.

During 1953, following the lime application, an intensive plankton bloom occurred, being primarily the result of increases in standing crop of *Dictyosphaerium Chrenbergianum* Naegeli, the colonies of which were retained by the plankton-trap net (number 20 silk bolting cloth). This bloom was responsible for the rise in *p*H and appearance of carbonate alkalinity due to carbon dioxide extraction discussed in relation to Fig. 1, and also for the corresponding decrease in light penetration.

During 1954, another intensive plankton bloom occurred which was responsible for the chemical changes shown in Fig. 1 and for the further reduction of light penetration. This bloom does not appear among the net-plankton data to the proper degree because it was composed primarily of *Microcystis aeruginosa* Küetzing, the cells of which were too small to be retained by the plankton-trap net, and secondarily of *Anabaena Viguieri* Denis and Fremy which was retained by the net.

During 1955, a plankton bloom consisting of *Anabaena Viguieri* was in progress when sampling commenced in the spring, which is shown in Fig. 2 and which was responsible for the chemical conditions shown in Fig. 1 for this date. Shortly after the subsidence of this bloom, another was initiated composed primarily of *Microcystis*; the *Microcystis* bloom again does not appear among the net-plankton data because the cells were too small to be retained by the plankton-trap net; however, the chemical

effects of the *Microcystis* bloom are reflected among the data of Fig. 1 showing the appearance of carbonate alkalinity and a rise in pH. The small increase in standing crop shown in Fig. 2 at the close of the summer sampling season was composed of *Anabaena Viguieri*, but apparently was not extensive enough to cause any chemical changes.

The volumetric determinations of zooplankton were made in a manner similar to the net phytoplankton, but no pertinent changes in standing crop were observed through the four years of sampling.

During the last two years of sampling (1954 and 1955), it was observed that one species of aquatic plant, *Myriophyllum tenellum* Bigelow, had increased markedly over much of the sand bottom. During 1955, the *Myriophyllum* invaded one of the bottom-fauna sampling stations, whereupon the average standing crop of bottom organisms increased about ten-fold. Extreme variation among the Ekman dredge samples was encountered, however, apparently due to the failure of the Ekman dredge to cut consistently through the *Myriophyllum* mat. Probably the standing crop of bottom organisms increased in those areas where the *Myriophyllum* increased, but no quantitative data were collected relating to aquatic plants, and it was difficult to draw any valid inference from the bottom-fauna data.

GROWTH OF FISH

Since the stunted yellow perch population was the group of primary interest, and since the abundance of the other species was so low as to preclude the collection of adequate samples, the analysis of growth was limited to the stunted perch.

Table 1 shows the age distribution of the fish in the stunted perch samples. As mentioned previously, the collections from this group were made by angling during 1952; a selectivity of the collecting method against the smaller fish may have caused the low numbers of age-group I to appear in the 1952 samples, but bag-seine samples collected the following year also showed a scarcity of age-group I fish. Through the next three years it became apparent that age-group I fish entered the samples in much greater proportion and the numbers of age-group III fish decreased. This would appear to indicate that, since the bag seine was highly selective as to the size of fish collected, an increase in growth occurred, causing the age-group I fish to enter the bag-seine samples in greater numbers, a corresponding decrease in the proportion of age-group III fish resulting; however, a conclusion of increased growth on this basis would probably be presumptive.

TABLE 1. — NUMBERS OF YELLOW PERCH OF DIFFERENT AGE GROUPS COLLECTED IN STONER LAKE, 1952–56

Age Group	Year of Collection				
	1952	1953	1954	1955	1956
I	2	5	27	63	59
II	13	22	22	15	39
III	24	21	6	11	2

In an analysis of growth, an attempt was made to compare yearly growth increments for each age group represented in the samples. Difficulty was encountered, however, with both age-group I and III fish due to the small numbers in the samples during the early years for age-group I and later years for age-group III. Consequently, only the age-group II fish were present in the samples for all years in large enough numbers for growth analysis. Table 2 shows the average calculated growth for the first and second years of life for the age-group II fish. It would appear that for the first year of life, progressive increases in growth occurred; however, the differences among the first three years are not statistically significant, and a significant increase occurs only between the samples of 1954 and 1955; the greater growth during the first year of life, observed among the 1955 collections, was made during 1953. For the second year of life, the increase occurs between the samples of 1953 and 1954; the greater growth during the second year of life, observed among the 1954 collections, was made also during 1953. In other words, an increase in growth occurred during 1953 for both years of life, which was also the year during which the greatest increase in standing crop of net phytoplankton occurred.

In order to make a comparison of the growth during the first year of life of those fish that obtained their growth before 1953

TABLE 2. — AVERAGE CALCULATED INCREMENTS IN TOTAL LENGTH (INCHES) FOR GROWTH AMONG TWO-YEAR-OLD YELLOW PERCH IN STONER LAKE, 1952–56

[Standard deviations in parentheses]

Year of Growth	Year of Collection				
	1952	1953	1954	1955	1956
1	2.75 (0.336)	2.70 (0.267)	2.85 (0.228)	3.04 (0.213)	3.07 (0.167)
2	0.85 (0.279)	0.83 (0.234)	0.91 (0.203)	0.91 (0.231)	0.91 (0.155)

(i.e., before the effects of lime application became apparent) with those that made their growth during 1953 and later (after lime application), the samples for 1952, 1953, and 1954 were averaged and compared with the average of the 1955 and 1956 samples. The former group averaged 2.77 inches, the latter 3.06 inches; the difference was highly significant when tested by the *t*-test. Similarly, for the growth during the second year of life, a "before-and-after" comparison was made between the average of the samples of 1952 and 1953 (growth obtained before 1953) and the average of the samples of 1954, 1955, and 1956 (growth obtained during 1953 and later); the former averaged 0.84 inch and the latter 0.91 inch; this difference was significant only at a level slightly less than 90 per cent. This might indicate that the young-of-the-year perch utilized the more abundant fish food to a greater extent than did the perch in their second year of life.

RELATIONSHIP BETWEEN ALKALINITY AND PRODUCTIVITY

Several mechanisms by which productivity may be increased in a soft-water lake through lime application have been suggested by various workers. Neess (*op. cit.*), in a review of pond fertilization in Europe, suggested that lime would be advantageous to the availability of nutrients by reducing the acidity which would otherwise retard decomposition of organic matter and the mineralization of nutrients, that the calcium in lime would displace other nutrients from organic colloidal systems, and that lime increases the ability of water to store carbon dioxide. Hasler, Brynildson, and Helm (*op. cit.*) added to this list the flocculation and precipitation of organic colloidal color of bog lakes, thus permitting deeper penetration of light and increasing the trophogenic zone. They were able to clear the color from bog lakes in Wisconsin, thus improving oxygen conditions for trout in deeper, cooler strata of water. Johnson and Hasler (1954) indicated that lime application may prevent winter kill by reducing the amount of oxygen-consuming organic matter. Waters (1957) demonstrated the release of phosphorus from bog-lake soils following the application of hydrated lime and presented data which indicate that the immediately available carbon dioxide (the sum of free carbon dioxide, carbon dioxide available in bicarbonates, and carbon dioxide produced by decomposition, atmospheric absorption, etc., over a given period of time) may limit the extent of plankton blooms; lime application increases the immediately available carbon dioxide by increasing the concentration of bicarbonates, i.e., by increasing the ability of the water to store carbon dioxide.

Thus, the sequence of effects following lime application may be from improved nutrient availability to increased phytoplankton production to increased production of fish-food organisms. In Stoner Lake, one species of aquatic plant, *Myriophyllum tenellum*, enlarged its range, and, although the meager quantitative data available do not prove an increased standing crop of bottom organisms, there were some indications that the bottom fauna was increased in those areas where the *Myriophyllum* increased. In Stoner Lake, no increases in zooplankton were observed; however, in two bog lakes to which lime was applied (Waters, *op. cit.*) the standing crop of zooplankton increased

following lime application. It is suggested that in Stoner Lake, the zooplankton population, under the heavy predation of an extremely large population of badly stunted fish, may have been already at the "threshold of security," and that an increase in zooplankton production was immediately absorbed by the perch through predation. A limited study of stomach samples collected during the years following lime application indicated that zooplankton was the principal item of diet among the young-of-the-year perch.

It was tentatively concluded that biological productivity was increased in Stoner Lake, apparently the result of lime application if it is assumed that the population size was relatively stable. The possibility exists, of course, that a change of population size occurred coincidentally with the lime application and was the cause of increased growth, rather than the changes resulting from lime application. Nothing was obvious, however, to indicate such a population change.

It should be pointed out that, despite the increased growth of fish, the majority of yellow perch in Stoner Lake remains badly stunted, though slightly less so than before. The effect of the lime application upon the yield to the angler is probably negligible, since the level of stunting has only been moved up slightly. Stunting remains because of the extremely unbalanced fish population, and in a proper management program of Stoner Lake there should be included the reduction of yellow perch and the introduction of a predator species. The small change in growth that the lime application apparently effected, however, probably reflects, in view of what was obviously an extremely large population, a considerable increase in the capacity of the lake to produce fish food.

Summary

Lime application was made to Stoner Lake, in the Upper Peninsula of Michigan, to test the hypothesis that increasing the alkalinity of a soft-water, unproductive lake would increase biological productivity. A small application of hydrated lime and an application of crushed limestone failed to increase the alkalinity, while larger applications of hydrated lime increased the alkalinity from 6 p.p.m. to 15 p.p.m. During a four-year study of limnological conditions following the application of hydrated lime several extensive phytoplankton blooms were observed which caused the appearance of carbonate alkalinity and the corresponding rise in *p*H due to the extraction of carbon dioxide by the phytoplankton. One species of aquatic plant, *Myriophyllum tenellum*, was observed to increase markedly over previously barren sand bottom, and the standing crop of bottom organisms increased at one sampling station which had been invaded by the *Myriophyllum*. The growth of stunted yellow perch in their first year of life increased significantly.

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ANALYSIS OF VARIATION AMONG PARTICIPANTS IN PHEASANT COCK-CROWING CENSUSES[1]

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The pheasant crowing-count was described by Kimball (1949) as a technique for determining spring population trends, distribution, movement, and even spring-storm mortality of cock birds of the ring-necked pheasant (*Phasianus colchicus*). Factors he listed as affecting the accuracy of this type of census were: (1) variation in the ability of individual observers to hear cock-calls, (2) daily trend and duration of maximum cock-crowing, (3) seasonal trend and duration of maximum cock-crowing, (4) uniformity of results, (5) variation in environmental factors such as weather and cover. Kozicky (1952) investigated some effects of weather and also discussed uniformity of results. Thompson and Lemke (1953) dealt with nonrandomness of pheasant calls.

The considerable extent to which individual observers apparently differ in hearing cock-calls was first noticed by the junior author while working with a summer field class. The usable data from that class were from the same six students on four days. At the same time that the pheasant call-counts were made, the observers also attempted to record the numbers of individual quail and doves heard calling. Analyses of variance of the pheasant counts indicated that there were either significant or highly significant differences between people on three of the four days. The question arose as to whether such differences also would be evident during the peak of the pheasant crowing season and when only pheasants (and not also doves and quail) were counted.

The writers are indebted to Don W. Hayne of the Department of Zoology at Michigan State University for assistance in statistical matters and to graduate students L. H. Blankenship, A. D. Geis, R. G. Housedorf, D. B. Reid, and C. R. Terman for considerable help in serving as experimental observers.

It is recognized that a larger number of observers would have been desirable, but there were difficulties in organizing a larger group who were willing to undertake the early-morning work without compensation when similar work for pay was available. Since similar difficulties might well be encountered by other investigators, it was thought desirable to present these findings despite their limitations.

Field Procedures

All cock-crowing counts used in this study were made on pheasant-census routes used annually by the Game Division of the Michigan Department of Conservation. With the exception of the last item listed below, counts followed the method used by that organization and also approximated that recommended by Kimball (*op. cit.*). The counts were made according to the following rules:

1. On each route, counting started exactly one-half hour before sunrise, and the route was covered as quickly as possible allowing exactly two minutes for each count.
2. All pheasant cock-crows (two-syllable calls) were counted, but no effort was made to identify individual birds.
3. Counts were made while standing 15 or 20 feet from the car to avoid any noises from the cooling motor.
4. On completing the count at a station, the counters drove as rapidly as possible to the next station.
5. Extraneous noises interfering with the count were noted at the stations where they occurred.
6. Counts were made only when the wind velocity was less than eight miles per hour as determined by the Beaufort wind scale.
7. All individual quail heard whistling, all individual doves heard cooing, and all individual grouse heard drumming were recorded.

Participants in the counting rode in one vehicle and made their two-minute counts simultaneously, but kept them secret from their fellow counters. Bovard (1953) demonstrated the importance of secrecy by

[1] The study was undertaken while the senior author was a candidate for the Master of Science degree at Michigan State University.

showing that groups making estimates greatly reduced the dispersion of their estimates after having been informed of their previous estimates and of the group norm.

Four or five two-minute trial counts were made on the first day of both the spring and summer counts of 1953. These were used only to demonstrate the method to participants with no previous counting experience. This was the only training provided the otherwise inexperienced persons tested.

A large number of counts were rejected because of poor weather conditions or because they were so low that analyses would have been meaningless.

STATISTICAL PROCEDURES

Data utilized in this study were subjected to analysis of variance. Independence of the mean was tested by use of Bartlett's Test for Homogeneity of Variance (Snedecor, 1946:249–252). Since a significant chi-square value was obtained by using the original data, i.e., pheasant calls, Bartlett's Test was repeated using the transformation

TABLE 1.—PHEASANT-CROWING COUNTS MADE SIMULTANEOUSLY BY SIX OBSERVERS, INGHAM COUNTY, MICHIGAN, APRIL 23, 1953

Stations	Observers: Experienced A	B	C	Inexperienced D	E	F
1	39	33	33	32	29	27
2	46	36	32	30	35	35
3	45	36	44	31	31	23
4	15	25	29	18	18	14
5	17	14	14	9	14	7
6	27	24	26	14	20	15
7	24	19	15	13	19	15
8	excessive interfering noises					
9	22	22	22	13	16	13
10	28	35	33	32	26	28
11	26	24	23	26	22	17
12	12	13	5	9	8	8
13	8	11	9	9	12	7
14	6	5	9	4	10	3
15	7	6	7	2	7	6
16	7	11	11	6	10	6
17	9	11	9	6	10	4
18	1	2	4	2	5	0
19	5	4	4	4	6	2
20	3	2	3	1	3	1
Totals	347	333	332	261	301	231

ANALYSIS OF VARIANCE

Source of Variation	DF	Sum of Sq.	Mean Sq.	*F*
Total	113	243.1998		
People	5	9.7641	1.9528	14.22**
Experienced	1	0.0104	0.0104	0.08
Inexperienced	3	6.5752	2.1917	15.78**
Exp. vs. Inexp.	1	3.1785	3.1785	22.32**
Stations	18	221.0792	12.2823	89.46**
Error	90	12.3565	0.1373	
Error (Exp.)	18	2.2947	0.1275	
Error (Inexp.)	54	7.4993	0.1389	
Error (Exp. vs. Inexp.)	18	2.5625	0.1424	

** Highly significant

$\sqrt{x + \frac{1}{2}}$ for each individual observation. This time the chi-square value was not significant, indicating that the mean and variance were now independent of each other. All analyses of variance were then completed using this transformation.

EFFECT OF PREVIOUS EXPERIENCE

During the spring of 1953, five graduate students and the senior author made counts of pheasant cock-crows over three routes, each of which was run twice. On three of these days only five people participated. Two students had conducted cock-crowing counts the previous spring for the state of Michigan and were therefore considered "experienced," while the other four had never made a cock-crowing count and were considered "inexperienced." Table 1 illustrates a typical day's count and its analysis. The record sheets were collected immediately following each day's counting and sealed in envelopes for future analysis. Counts were started during the period of maximum seasonal crowing intensity but were not concluded until well after the seasonal peak. The results of six days of counting are shown in Table 2. Statistical analysis of these data revealed that: (1) Total counts of all participants agreed on only one of six days. (2) Total counts of experienced people agreed on five of six days. (3) Total counts of inexperienced people agreed on only one of six days. (4) Total counts of inexperienced people were lower than and failed to agree with those of experienced people on four of six days.

During trial counts made prior to the first day's counting, one inexperienced student consistently obtained lower counts than any of the other participants. Assuming that this person probably would not be selected by anyone screening observers for the purpose of making cock-crowing counts, analyses were again conducted with his counts excluded. These are summarized in Table 3, from which it may be seen that: (1) Total counts of all participants agreed on only two of six days. (2) Total counts of experienced people agreed on five of six days. (3) Total counts of inexperienced people agreed on three of six days. (4) Total counts of inexperienced people failed to agree with those of experienced people on two of six days.

On two days, inexperienced observers' counts differed significantly among themselves, but did not differ from counts of

TABLE 2.—STATISTICAL DATA INDICATING VARIATION WITHIN AND BETWEEN GROUPS IN HEARING PHEASANT CALLS, SOUTHERN MICHIGAN, 1953

Date	Source of Variation	DF	Sum of Squares	Mean Squares	*F*
Apr. 16	Experienced	1	0.4232	0.4232	3.13
	Inexperienced	2	3.0333	1.5166	7.05**
	Exp. vs. inexp.	1	12.8280	12.8280	151.63**
Apr. 21	Experienced	1	2.6368	2.6368	27.10**
	Inexperienced	3	15.8185	5.2728	23.61**
	Exp. vs. inexp.	1	2.0406	2.0406	6.61**
Apr. 23	Experienced	1	0.0104	0.0104	0.08
	Inexperienced	3	6.5752	2.1917	15.78**
	Exp. vs. inexp.	1	3.1785	3.1785	22.32**
Apr. 24	Experienced	1	0.1820	0.1820	2.33
	Inexperienced	3	8.3711	2.7904	21.80**
	Exp. vs. inexp.	1	3.5926	3.5926	22.30**
May 19	All people	4	0.7546	0.1886	0.83
June 15	Experienced	1	0.0561	0.0561	0.42
	Inexperienced	2	10.5708	5.2854	28.80**
	Exp. vs. inexp.	1	0.0218	0.0218	0.19

** Highly significant

TABLE 3.—VARIATION WITHIN AND BETWEEN GROUPS IN HEARING PHEASANT CALLS, SOUTHERN MICHIGAN, 1953, SHOWING THE EFFECT OF SCREENING INEXPERIENCED COUNTERS

Date	Source of Variation	DF	Sum of Squares	Mean Squares	*F*
Apr. 16	Experienced	1	0.4231	0.4231	3.13
	Inexperienced	1	0.1975	0.1975	0.94
	Exp. vs. inexp.	1	6.6672	6.6672	62.12**
Apr. 21	Experienced	1	2.6368	2.6368	27.10**
	Inexperienced	2	1.8223	0.9112	9.36**
	Exp. vs. inexp.	1	0.0297	0.0297	0.13
Apr. 23	Experienced	1	0.0104	0.0104	0.08
	Inexperienced	2	2.7064	1.3532	9.81**
	Exp. vs. inexp.	1	1.1434	1.1434	6.47*
Apr. 24	All people	4	1.2492	0.3123	1.87
May 19	All people	4	0.7546	0.1886	0.83
June 15	Experienced	1	0.0561	0.0561	0.42
	Inexperienced	2	10.5708	5.2854	28.80**
	Exp. vs. inexp.	1	0.0218	0.0218	0.19

* Significant
** Highly significant

experienced observers. On April 21, this agreement was due to failure of the experienced people's counts to agree among themselves. On June 15, one inexperienced counter made an exceedingly high count, making the mean count of his group higher than that of the experienced people. This phenomenon was noted by Kimball (*op. cit.*), who stated: "An inexperienced worker will usually have low counts at first, and this is often followed by excessive counts due to misinterpretation of other sounds or to imagination."

EFFECT OF INTERFERENCE

On five days, stations having interference were prevalent enough to make feasible the comparison with stations not having interference. Interference was defined as extraneous noises such as those of songbirds, frogs, heavy traffic, or farm noises which might mask a portion of the pheasant calls or distract the counters. The highly significant differences that were found among the counts at all stations, whether or not interference was present, were simply an indication that crowing pheasants were unequally distributed. It seemed more important that on all days significant differences were found between the counts at stations with interference and those at stations without interference. However, closer examination seemed to indicate that this test was not valid, since interference was much more common toward the ends of the routes. It appears to be influenced by the position of the stations on the route and hence by time in relation to sunrise.

Tests comparing the variability among counts at stations without interference and the variability among counts at stations with interference showed significance at the 10 per cent level only once, and then the noninterference stations had the higher variance. Variation among counters at stations with interference also differed only once at the 10 per cent level from variation among counters at stations without interference, and again the noninterference variance was the higher.

EFFECT OF MULTIPLE-SPECIES COUNTS

During the summer of 1953 an attempt was made to test whether or not counting calls of bob-white quail (*Colinus virginianus*) and mourning doves (*Zenaidura macroura*) simultaneously with pheasant calls had any effects on the recorded numbers and variation among pheasant calls. Accordingly, nine students and the authors were divided into two groups. One group counted the total pheasant calls, and indi-

vidual quail and doves heard calling. The second group counted only the total pheasant calls. Each group was subdivided into experienced and inexperienced counters. Anyone who had made cock-crowing counts prior to that summer was considered to be "experienced." Two counts were made, one over a 20-station route and one over a 15-station route. The results of this experiment were inconclusive. In general, there was a lack of agreement among all groups.

Because the results of the 1953 multiple-species counts were so unsatisfactory, the experiment was conducted again in 1955. This time the group was divided into four sections; three people counted pheasants, doves, and quail, while three smaller groups of two people each counted pheasants only, doves only, and quail only, respectively. The results of these counts are shown in Table 4. It may be seen that: (1) All counters agreed among themselves on only two of seven occasions. (2) Single-species counters agreed among themselves on six of seven occasions. (3) Multiple-species counters agreed among themselves on four of seven occasions. (4) Multiple-species counters agreed with single-species counters on

TABLE 4.—STATISTICAL DATA INDICATING VARIATION WITHIN AND BETWEEN GROUPS IN MAKING MULTIPLE-SPECIES COUNTS, SOUTHERN MICHIGAN, 1955

A.—Pheasants Only Compared with Pheasants, Doves, and Quail[1]

Date	Source of Variation	DF	Sum of Squares	Mean Squares	F
June 22	1. Pheas. only	1	0.0775	0.0775	1.07
	2. Pheas., doves, and quail	2	3.0493	1.5246	9.70**
	3. (1) vs. (2)	1	0.8740	0.8740	0.80
June 27	All people	4	0.6615	0.1655	1.58

B.—Quail Only Compared with Pheasants, Doves, and Quail[1]

June 22	1. Quail only	1	0.7595	0.7595	15.82**
	2. Pheas., doves, and quail	2	0.3683	0.1842	1.81
	3. (1) vs. (2)	1	0.0810	0.0810	0.61
June 24	1. Quail only	1	0.0221	0.0221	0.37
	2. Pheas., doves, and quail	2	0.6226	0.3113	6.43**
	3. (1) vs. (2)	1	2.0769	2.0769	52.71**

C.—Doves Only Compared with Pheasants, Doves, and Quail

June 22	1. Doves only	1	0.1277	0.1277	2.29
	2. Pheas., doves, and quail	2	1.8640	0.9320	31.07**
	3. (1) vs. (2)	1	0.0085	0.0085	0.002
June 24	1. Doves only	1	0.1103	0.1103	2.65
	2. Pheas., doves, and quail	2	0.5523	0.2762	2.61
	3. (1) vs. (2)	1	0.4772	0.4772	7.75*
June 27	All people	4	0.2463	0.0616	1.07

[1] Pheasant counts for June 24th and quail counts for June 27th were not analyzed because it was felt they were so low that analyses would have been meaningless.

* Significant
** Highly significant

five of seven occasions. On three of these the agreement was probably due to the highly significant differences within one or the other of the groups.

SUMMARY

Pheasant cock-crowing counts made by groups of people selected with no regard for their previous experience at counting showed very poor agreement. Cock-crowing counts made by two experienced counters were generally higher and agreed among themselves more frequently than did counts of four inexperienced people. The elimination of one participant who showed an obvious lack of ability at counting tended to improve the agreement among the counts of the remaining participants. Variation among counters was no greater at stations with interference present than at stations where it was absent. Three groups making single-species call counts obtained markedly greater agreement among themselves, regardless of the species, than did one group counting simultaneously but attempting to count the calls of three species.

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MOVEMENTS OF WHITE-TAILED DEER TAGGED IN MINNESOTA

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Observations in northwestern Minnesota have led us to believe that, in the prairie-deciduous forest type of habitat, white-tailed deer (*Odocoileus virginianus*) are more wide-ranging than they are in the coniferous forest habitat. This paper compares the movements of tagged white-tailed deer in the coniferous forest area of northern and eastern Minnesota with those occurring in the prairie–deciduous forest type of habitat as represented by the Mud Lake National Wildlife Refuge in northwestern Minnesota. Only those deer which were released at the point of trapping and recovered as hunter kills are considered here.

MOVEMENTS IN CONIFEROUS FOREST AREAS

Ear-tagging of deer in Minnesota was initiated in 1935 by Gustav A. Swanson, then a biologist with the State Conservation Department. Actual field work was carried on through 1942 by members of the U.S. Forest Service, National Park Service, C.C.C., Resettlement Administration, State Rangers and State Game Wardens in the Superior National Forest, various state forests and in Itasca State Park (Fig. 1). The terrain of these areas varies from gently rolling to fairly hilly, and the more important coniferous trees are black spruce (*Picea mariana*), white spruce (*P. glauca*), tamarack (*Larix laricina*), jack pine (*Pinus banksiana*), white pine (*P. strobus*), red pine (*P. resinosa*), balsam fir (*Abies bal-*

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[2] Minnesota Conservation Department, Pittman-Robertson Project, W-11-R-15.

TABLE 1.—DEER-TAGGING OPERATIONS IN MINNESOTA CONIFEROUS AREAS

Trapping Areas	1935	1936	1937	1938	1939	1941	1942	Total
1. Superior National Forest	9	129	163	59	103	28	6	497
2. Cloquet Valley State Forest	—	3	46	—	5	9	—	63
3. George Washington State Forest	—	—	—	3	—	9	—	12
4. Beltrami Island State Forest	—	—	4	4	12	—	—	20
5. Grand Portage State Forest	—	—	4	—	—	—	—	4
6. Kabetogama State Forest	—	6	—	—	—	—	—	6
7. Itasca State Park	—	98	71	—	—	—	—	169
8. St. Croix State Park	—	10	—	—	—	—	—	10
Totals	9	246	288	66	120	46	6	781

samea), and northern white cedar (*Thuja occidentalis*). The purpose of the project was to study the seasonal movement and distribution of the deer. Table 1 shows the numbers of deer tagged each year in the various areas (Morse and Burcalow, 1941).

A total of 781 deer were tagged (Table 1). Of this number, 722 were trapped in February and March with Stephenson-type box traps while 55 were run down in deep winter snows. Four were tagged as fawns in the spring and early summer. Of the total, 174 were adult males, 212 adult females, 151 male fawns, 158 female fawns and 86 were of undetermined sex and/or age.

Tag recoveries reported to date from all sources amount to 104 or 13 per cent of the total number tagged. Of this number, hunters have reported 75, and the other 29 were found dead or were killed in miscellaneous accidents. Since some of these deer were released away from the place of trapping, data from only 63 of the hunter kills were used in calculating distances moved (Table 2) in order to make the data strictly comparable. The majority of these returns has been compiled by Morse and Burcalow

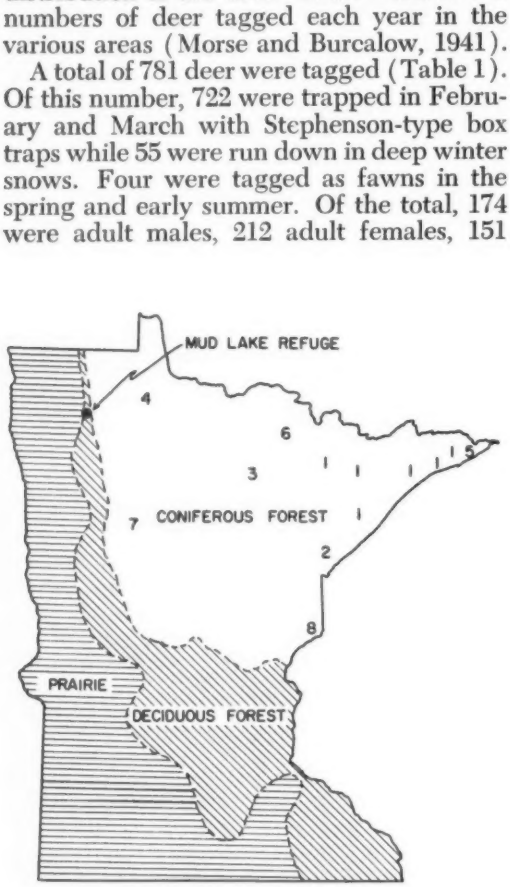

FIG. 1. Minnesota habitat types. Numbers denote areas where deer tagging has been carried out. A key to the numbers is given in Table 1.

TABLE 2.—MOVEMENTS OF TAGGED DEER IN MINNESOTA CONIFEROUS AREAS

Distance Moved in Miles	Males	Females	Total	Per Cent (Cumulative)
Less than 0.5	2	3	5	8
1	2	5	7	19
2	4	6	10	35
3	5	1	6	44
4	2	4	6	54
5	1	5	6	63
6	1	2	3	68
7	6	2	8	81
8	1	1	2	84
9	–	1	1	86
10	–	1	1	87
11	–	1	1	89
12	3	–	3	94
14	1	–	1	95
15	1	–	1	96
20	1	–	1	98
22	1	–	1	100
Totals	31	32	63	

(1941), and our purpose in reviewing them here is to compare them with the more recent work done at the Mud Lake National Wildlife Refuge.

Eighty-one per cent of these coniferous forest deer were shot within seven and one-half miles of the trapping site. Males moved the farthest, averaging 6.7 miles; females moved an average of 3.7 miles; and the average distance for both sexes was 5.1 miles. The longest movement was made by an adult buck which was shot 22 miles from the point of capture eight months after being tagged. The longest movement by a doe was 10.8 miles.

The time lag between tagging and tag recovery was greater for females than males. All of the recoveries of males were made within a six-year period after tagging while three of the females were recovered between seven and nine years after tagging. Seventy-eight per cent of the hunter kills were made within three years after the date of tagging.

Fifteen tags were recovered at the original point of capture, mostly by retrapping. An adult buck and an adult doe were retrapped at the original trapping site four years after tagging.

MOVEMENTS IN PRAIRIE–DECIDUOUS FOREST

Mud Lake National Wildlife Refuge lies in an ecotone of northwestern Minnesota with the prairie, deciduous forest and coniferous forest all closely associated. The general terrain is very flat. There is only a twenty-foot difference in elevation from the highest to lowest point on the 60,000-acre area. Deer consistently utilize about 35,000 acres of the total refuge area; the remaining area is marsh and open water. The primary tree species are: willow (*Salix* sp.) of which nine species have been identified, aspen (*Populus tremuloides*), balsam poplar (*P. balsamifera*), American elm (*Ulmus americana*), boxelder (*Acer negundo*), green ash (*Fraxinus pennsylvanica*), black spruce, and tamarack.

White-tailed deer were rare in the general area until about 1920 when they began to increase slowly. In the late 1930's, deer became more common. The refuge was established in 1937 when it was estimated that there were about 25 deer in the area. From 1937 through 1946 there were no systematic counts, but the general trend of the deer population was one of steady increase. The first airplane census was made in 1947 when 742 deer were counted (Hunt and Mangus, 1954). Since that time an aerial census has been made each winter and the population has fluctuated from a high of 1,300 in 1949 to a low of 640 in 1956 (Table 3).

The trapping and ear-tagging of deer were initiated on Mud Lake Refuge in 1947. Tagging activities have been carried on each year during the months of January, February and March using Stephenson-type box traps. The number tagged has varied between 3 and 75 deer per year for a total of 253 through the winter of 1955–56. The percentage of the herd tagged during a given year has varied between 0.4 and 12 based

TABLE 3.—DEER-TAGGING OPERATIONS, MUD LAKE NATIONAL WILDLIFE REFUGE

Year	Approx. Winter Population	No. Deer Tagged	Per Cent of Winter Population Tagged Each Year	Returns Shot on Refuge	Returns Shot Outside Refuge
1947	742	3	0.4	—	—
1948	897	26	3	—	—
1949	1,300	23	1.8	4	2
1950	850	36	4	No Season	
1951	864	20	2	3	2
1952	844	20	2	3	3
1953	680	19	3	4	6
1954	645	18	3	3	4
1955	660	13	2	2	1
1956	640	75	12	18	2
Totals		253		37	20

on the estimated winter population (Table 3). Of the 253 deer tagged, 34 were adult males, 44 adult females, 93 male fawns and 82 female fawns. All deer were released at the point of tagging.

Between 17,000 and 21,000 acres of deer habitat on the refuge have been open to public deer hunting each year since 1949 with the exception of 1950 when there was no state season. Tags have been recovered each year both inside and outside the refuge. A total of 57 hunting-season kill recoveries have been recorded (Table 4). This figure represents 23 per cent of the total number of deer tagged. The higher rate of recovery at Mud Lake Refuge is due, in part at least, to several factors which include relative accessibility of the area to hunters, difference in starvation losses, and the fact that checking stations were operated there.

TABLE 4.—MOVEMENTS OF TAGGED DEER: MUD LAKE NATIONAL WILDLIFE REFUGE, 1947–56

Distance Moved in Miles	Males	Females	Total	Per Cent (Cumulative)
1	3	17	20	35
2	4	8	12	56
3	1	–	1	58
4	2	1	3	63
5	1	–	1	65
7	–	2	2	68
9	2	1	3	74
11	–	1	1	75
12	1	–	1	77
15	–	1	1	79
17	1	–	1	81
18	1	–	1	82
20	–	2	2	86
30	–	1	1	88
34	1	–	1	89
35	1	1	2	93
43	1	–	1	95
45	2	–	2	98
55	–	1	1	100
Totals	21	36	57	

The average distance in air miles from the point of tagging to the place of kill was 9.7 miles. Bucks averaged 14.0 miles while does averaged only 6.8 miles. Twenty of the 57 tag recoveries were from outside the refuge boundaries. Movements of 45 miles by two young bucks were recorded, but the longest movement was that of a 2½-year-old doe which was shot 55 air miles from the place of tagging.

The time lag between tagging and tag recovery was also greater for females than males at Mud Lake Refuge (Table 5). All of the recoveries of males were made within a four-year period after tagging, while nine recoveries of females were made between five and seven years after the time of tagging. Seventy-four per cent of the tag recoveries were made within three years of the time of tagging.

TABLE 5.—TIME INTERVAL BETWEEN TAGGING AND RECOVERY

Time Interval in Years	Males	Females	Total	Per Cent (Cumulative)
Minnesota Coniferous Areas				
1	14	8	22	35
2	6	10	16	60
3	5	6	11	78
4	2	2	4	84
5	3	1	4	90
6	1	2	3	95
7	–	1	1	97
8	–	–	–	97
9	–	2	2	100
Totals	31	32	63	
Mud Lake Refuge				
1	10	13	23	41
2	7	9	16	69
3	2	1	3	74
4	2	4	6	85
5	–	6	6	95
6	–	1	1	97
7	–	2	2	100
Totals	21	36	57	

All tag recoveries from distances exceeding nine and one-half miles have been of deer 2½ years old or younger. Some deer were tagged as fawns and therefore were of known age and the others were aged by the tooth wear method. These long-distance recoveries of young deer composed 28 per cent of the number of tag recoveries and 6 per cent of the total number of deer tagged. The 1½- and 2½-year age groups had moved the longer distances (Table 6). We interpret this to mean that these refuge deer

were ranging out considerable distances during their early years and then gradually diminishing their wanderings as they grew older.

TABLE 6.—MOVEMENTS OF TAGGED REFUGE DEER BY AGE CLASS, 1947–56

Age Class at Kill	Number of Deer	Average Distance in Air Miles from Place of Tagging
1½	13	16.9
2½	16	16.6
3½	3	4.3
4½	2	5.0
5½	6	1.3
6½	4	1.2
7½	1	1.0
8½	1	1.0
Totals	46	

Although retraps of tagged deer have been numerous, the practice of checking the tags on retrapped deer was discontinued after 1952. Simply reading the number on the tag would involve a considerable amount of handling of the deer with the danger of injury. Most of the retraps were fawns which would be caught repeatedly the same year.

CONCLUSIONS

In conclusion, the data indicate that ear-tagged deer moved greater distances in the prairie–deciduous forest type of northwestern Minnesota than they did in the coniferous forest type of northern and eastern Minnesota. In both types about three-fourths of the deer were recovered within a three-year period after tagging. The time lag between tagging and recovery was greater for females than males in both types of areas. A breakdown by age classes for the Mud Lake Refuge deer shows that the younger deer moved much longer distances than the older deer. The available data for deer tagged in the coniferous forest type cannot be broken down by age class.

SUMMARY

This paper deals with the tag returns from 1,034 white-tailed deer which have been tagged in Minnesota from 1935 to 1956. Of this number, 781 deer were tagged from 1935 to 1942 in the coniferous forest type of habitat. The remaining 253 were tagged from 1947 to 1956 at the Mud Lake National Wildlife Refuge in the prairie–deciduous forest type of habitat. Hunters have provided 75 recoveries (10 per cent) of the 781 deer tagged in the coniferous area and 57 recoveries (23 per cent) of the 253 deer tagged on the Mud Lake Refuge. The longest movement in the Minnesota coniferous forest area was 22 miles and the average was 5.1 miles. For the Mud Lake Refuge, the longest return was 55 miles and the average was 9.7 miles. In the Minnesota coniferous area, 78 per cent of the recoveries were made within three years after tagging. For the Mud Lake Refuge, 74 per cent of the recoveries to date have been made within a three-year period after tagging. It is highly probable that more recoveries will be obtained in the next few years. Breaking down the movements of Mud Lake Refuge deer by age classes indicated that the younger deer moved much longer distances than the older deer. These data indicate that deer in the prairie–deciduous forest type of habitat are wider ranging than deer in the coniferous forest habitat.

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RECLAMATION OF COAL STRIP-MINED LANDS WITH REFERENCE TO WILDLIFE PLANTINGS[1]

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The initial reclamation of coal strip-mined lands in Ohio in 1923 consisted largely of a few scattered forest plantings including black locust (*Robinia pseudoacacia*), red pine (*Pinus resinosa*), red oak (*Quercus rubra*), and Corsican pine (*Pinus nigra poiretiana*) (Kelsey and Dayton, 1942). Large-scale reclamation of such areas did not begin until 1940, and for a number of years only the forest and grazing phases of land use were considered.

Research pertaining to the reclamation of coal strip-mined lands was not initiated until 1937 when personnel of the Central States Forest Experiment Station of the U.S. Forest Service established forest plantings on such areas in southern Ohio (Chapman, 1944). The potentialities of reclaimed coal strip lands for the production of wildlife habitat was not fully realized until preliminary studies in Illinois revealed the utilization of the existing habitat by a number of game species (Yeager, 1941). Since 1946, research conducted by the author on such areas in Ohio has indicated that, by the application of proper management techniques, habitat could be developed which would be capable of supporting wildlife populations equal to and in some instances surpassing those on adjacent undisturbed forest and croplands (Riley, 1954).

At the present time the majority of the coal strip-land acreage in Ohio is reclaimed either through the planting of trees or by seeding grasses and legumes for grazing. Extensive pasture seedings are made on spoils in the Harrison, Jefferson, and Belmont County areas due to the high percentage of limestone and calcareous shales in the overburden. Trees are generally used to reclaim those spoil areas that have a pH below 6.0. Although forestry and grazing have been the major phases of reclamation, wildlife habitat development has been coordinated with the over-all program in recent years. A number of plant species are utilized in various ways to develop favorable habitat for the wildlife species native to unglaciated southeastern Ohio.

Wildlife plantings are usually placed as borders around a reclaimed area, in haul roads, in old field areas, on the slope of the perimeter bank, around ponds, on undisturbed islands, in gullies, in ravines where machinery cannot traverse, as strips through forest plantations, and in areas seeded to pastures.

Objectives

The data presented in this paper are part of a comprehensive study conducted during the period from April 1947 to July 1951. Data from additional research conducted during the period from June 1954 to October 1955 are also included because of the need for information with which to plan properly the reclamation and management of the ever-increasing acreage of coal strip lands available for the production of wildlife habitat. The author traveled in 27 Ohio counties containing coal strip lands, plus seven counties in Indiana and five in Illinois. Data collected in the latter two states are not presented in this paper.

The objectives of the study were: (1) to evaluate the success and utility of various plant species in the production of wildlife habitat on coal strip lands; and (2) to develop suitable management practices for the production of wildlife habitat in conjunction with the forestry and grazing. No attempt will be made in the present report to document the actual effects of each plant species upon wildlife populations.

[1] The majority of the data are from research conducted for the doctoral dissertation of the author in the Graduate School of the Ohio State University under the direction of Dr. Charles A. Dambach, Associate Professor, Department of Zoology and Entomology. During the study the author held a Wildlife Research Fellowship provided by the Ohio Cooperative Wildlife Research Unit. Additional financial aid was furnished by the Ohio Reclamation Association through the Graduate School, the Ohio State University.

COAL STRIP MINING IN OHIO

The open-pit method of coal mining, usually referred to as strip mining, began in Ohio in the middle of the nineteenth century. During the early phases of the industry, hand shovels and wheelbarrows or horse-drawn scrapers were used to remove the overburden from the underlying coal seam.

Large-scale coal production by strip mining did not occur until 1914 with the advent of the power steam shovel, which was then employed in overburden removal. With the occurrence of the two World Wars, the increase in industrial demands for cheap fuel and the increase in size and efficiency of power shovels, the strip-mine industry expanded until it now produces about 63 per cent of the total coal production in Ohio. During the year 1954, Ohio produced a total of 31,472,066 tons of coal, 19,761,155 tons of which came from strip mines (Ohio Department of Industrial Relations, 1954).

The overburden or "spoil material" is removed to expose the underlying coal seam. It is piled adjacent to the exposed coal seam in long linear ridges that approximately parallel the contour of the landscape. After the coal has been removed from an area, the disturbed overburden material is graded to a gently rolling topography and revegetated by planting trees and shrubs or by seeding grasses and legumes. The 98th Ohio General Assembly, 1949–50, enacted the *Coal Strip Mine Land Reclamation Act* requiring the operator to reclaim the disturbed land by grading the spoil surface and revegetating it according to certain specifications outlined either in the law or by the administering agency, the Division of Reclamation of the Ohio Department of Agriculture. The 101st Ohio General Assembly, 1955–56, amended certain sections of the law with the objective of attaining better land reclamation.

The strip mining of coal occurs in 27 counties, chiefly in unglaciated southeastern Ohio (Fig. 1). In January 1950, there were about 47,625 acres of coal strip lands in Ohio; approximately 42 per cent of this acreage occurred in Harrison and Jefferson counties. Other rather large units of strip lands were located in Tuscarawas County —4,452 acres, Columbiana County—4,049 acres, and Perry County—3,770 acres. As of December 31, 1949, approximately 22,303 acres had been planted or seeded to trees, shrubs, legumes, and grasses, or were well covered by volunteer vegetation. Over much of the remaining 25,322 acres volunteer vegetation was present in various stages of succession. An estimated 50 per cent of the vegetation present on the reclaimed strip lands consisted of forest species. Since January 1, 1950, strip mining has affected approximately 55,081 acres, resulting in a total affected area of about 102,706 acres as of January 1, 1956 (Ohio Division of Reclamation, 1955).

METHODS

A total of 72 study areas were investigated, of which 71 were located on ungraded strip lands established prior to enactment of the present legislation. The vegetation consisted of 37 species that had been planted or seeded, including nine species of legumes, five species of grasses, five species of shrubs, eight species of conifers, and eight species of hardwoods, in addition to several volunteer or native tree, shrub, vine, and herbaceous species. The author was able to obtain complete data on the history of 66 of the study areas, including 24 that had been established either by or under his personal direction. The history of the remaining six areas was obtained from increment borings in trees, and from land owners or individuals who had been associated with the mining operation.

The study areas were selected on the basis of the spoil type and age of the spoil material, site conditions, the age of the vegetation, and the species composition of the vegetative unit or plant community. The selected study areas included plant communities consisting of volunteer trees, shrubs, and herbaceous coverts up to 34 years of age, legume seedings 23 years old, conifer plantations 23 years old, and hardwood plantations 25 years old.

Investigation of the vegetation was confined principally within a belt transect 12 feet wide extending throughout the study unit. Transects were located through the center of the plantation or seeding, and perpendicular to the long axis of the spoil bank. Within each transect, quadrats 25 square feet each were located in the ravines, midway on the slope and on the ridge. Data

collected within the transect included identification, survival, d.b.h., and height of trees, and survival and height of shrub species, food and cover present, and degree and length of slope. More detailed studies were made within the quadrats to determine the height, composition, and density, or percentage of undergrowth, covering the spoil surface. The *p*H of the spoil material was determined by testing samples taken from quadrats on the ridge, slope, and ravine. Tree diameters were measured at breast height using a diameter tape, while heights were measured using a collapsible 15-foot rule. Heights in excess of 30 feet were estimated. The slopes were measured using a slope board and steel tape, while soil tests were made using a Soiltex Testing Kit.

The entire study area or vegetative unit was then evaluated in terms of its usefulness in providing suitable wildlife habitat.

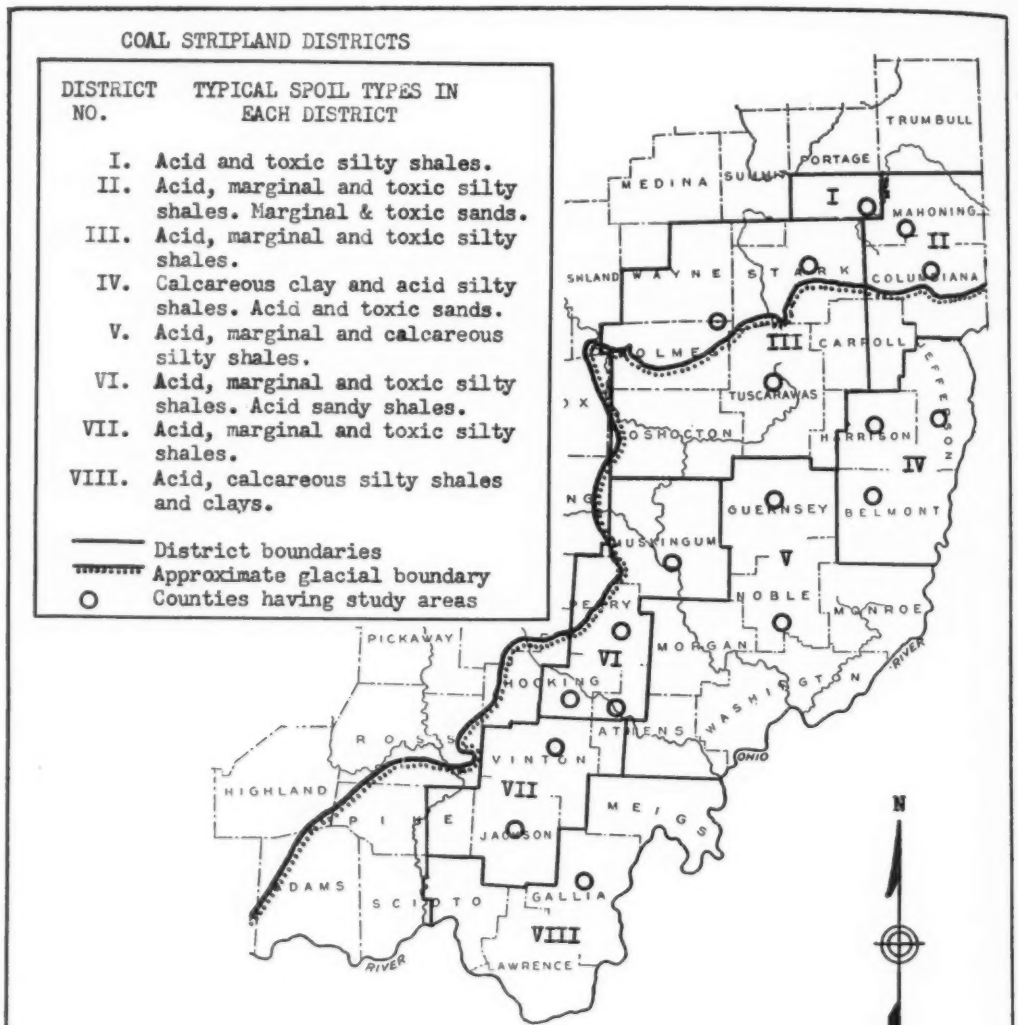

FIG. 1. Ohio coal strip-mining counties.

FACTORS EFFECTING SUCCESSFUL RECLAMATION

The successful revegetation of coal strip-mined lands is dependent upon several factors. Prior to the enactment of legislation, the topography of ungraded coal strip lands contained all exposures: north, south, east, and west. The resulting spoil banks included slopes from 5° to 55°, with the majority being 20° to 25°, and ranging up to 80 feet in length. The degree and length of slope are important in determining the rate of runoff and infiltration, degree of erosion, and the amount of spoil slipping and sloughing that may disturb or destroy areas of vegetation. Topography is probably of greatest importance up until the time ground cover is established or until the forest canopy closes. Exposure affects plant growth and survival through variations in temperature and moisture. Soil-surface temperatures recorded on an average July day (Meyer and Anderson, 1944) in 1948 within a 23-year-old red oak plantation ranged from 75.2°F. to 78.8°F., while within a similar-aged red pine planting temperatures registered 73.4°F. Surface temperatures in the same area exposed to direct sunlight registered 102.2°F. Natural red pine reproduction occurred on waste coal and clay where temperatures were recorded at 100°F. (Riley, 1952).

The acidity and alkalinity of the spoil material vary greatly due to differences in the geologic strata. Variations in the *p*H of spoil material ranged from 3.5 to 8.5 on the areas studied. In many instances this range was found within the space of one acre. The spoil acidity is probably the most important single factor determining the success of a particular plant species. Limstrom and Merz (1948) classified the spoil material in Ohio as 57.6 per cent acid, 41.8 per cent calcareous, and 0.6 per cent a mixture of the two.

The effect of the texture of the spoil material is important in its influence on soil structure, which is reflected in plant-growth rates, water-holding capacity, aeration, and the age at which the spoils can be planted. Texture of the spoil material is also important in determining the degree of compaction resulting from the heavy equipment used in grading operations. Variations in texture also affect acidity and fertility of the spoil material through the rate of leaching, infiltration, and percolation.

EVALUATION OF PLANT SPECIES

Legumes–Grasses (Table 1)

Three species of shrub and bush lespedeza (*Lespedeza cyrtobotrya, L. thunbergii* and *L. bicolor*) made excellent growth when planted or seeded on spoils with a *p*H range from 3.5 to 7.5. After four growing seasons, individual plants ranged up to 96 inches in height. (Better cover resulted from the seeding of these species than when seedlings were planted with a four-foot spacing.) An enormous amount of viable seed was produced after the first growing season. By the end of the eighth year, bicolor lespedeza appeared to be the most successful of the three species, being more numerous, having more vigor, making better growth, and producing a far better seed crop.

Korean lespedeza (*L. stipulacea*) seeded on spoils with a *p*H below 6.0 did not produce habitat comparable to the bush and shrub species. Germination was very poor on the more acid spoils, but when seeded on spoils high in limestone, 95 per cent of the spoil surface was covered the first year. Although Korean lespedeza is an annual plant, seedings were extremely prolific and vigorous at the end of the fourth growing season on areas containing much limestone.

Serecia lespedeza (*L. cuneata*) was of considerably more value than Korean lespedeza. A six-year-old and eight-year-old serecia seeding provided 50 and 95 per cent spoil-surface coverage with a maximum height of 48 inches. Serecia growing on slightly acid spoil was doing considerably better than on the spoils near the neutral or alkaline range. This species also spread rather rapidly to adjacent areas.

Of the lespedezas studied, bicolor and serecia show the most promise for widespread use on the coal strip lands of Ohio because their more successful germination and survival result in a more profuse cover.

Korean, cyrtobotrya and thunbergii appeared to be more exacting in site requirements and tended to fail during the later years. Both species provided food in the form of browse and seeds; of the two, serecia provided the more dense cover.

Six seedings of sweet clover (*Melilotus alba* and *M. officinalis*) ranging in age from

TABLE 1.—EVALUATION OF LEGUMES AND GRASSES

Species	Age of Unit (Years)[1]	Age of Spoil (Years)	Spoil Type[2]	Length and Degree of Slope	pH Range	Survival (Per Cent)	Height (Range or Average)	Best Site
Bush lespedeza	P 4	28	3	10′–50′ 20°–30°	3.5–7.5	20 N-S[3] 10 E-W	12″–96″	ravine, lower slope
Thunbergii lespedeza	P 4	28	3	10′–40′ 20°–30°	3.5–7.5	21 N-S 14 E-W	14″–65″	ravine, lower slope
Shrub lespedeza	P 4	28	3	10′–40′ 20°–30°	4.5–6.5	55 N-S 35 E-W	20″–96″	slope, ravine
Shrub lespedeza	P 5	30	3	10′–50′ 20°–35°	4.5–7.2	96	36″–96″	ravine
Serecia lespedeza	S 4	28	3	10′–40′ 20°–30°	4.5–6.0	10 N-S 73 E-W	24″–36″	slope, ravine
Serecia lespedeza	S 6	7	5	20′–30′ 20°–40°	5.0–6.5	50	36″	lower slope, ravine
Serecia lespedeza	S 8	10	2	10′–30′ 5°–30°	5.0–6.5	95	48″	equal
Korean lespedeza	S 4	28	3	10′–40′ 20°–30°	4.5–5.8	5 N-S 5 E-W	10″	lower slope, ravine
Korean lespedeza	S 4	5	5	20′–100′ 1°–10°	7.5–8.0	95	10″	equal
White sweet clover	S 4	28	3	10′–40′ 20°–30°	4.5–5.5	98 N-S 30 E-W	40″–46″	slope, ravine
Yellow sweet clover	S 4	28	3	10′–40′ 20°–30°	4.5–5.5	5 N-S 10 E-W	40″–48″	lower slope, ravine
White sweet clover	S 8	10	4	10′–60′ 27°–35°	5.0–7.0	50	18″	slope, ravine
White sweet clover	S 14	17–19	2	15′–40′ 31°–33°	4.0–6.9	45	36″	ravine
Yellow and white sweet clover	S 23	26	4	15′–50′ 20°–30°	4.5–7.3	15	30″	ravine
Alsike clover	S 4	28	3	10′–40′ 20°–30°	4.5–6.0	5 N-S 0 E-W	8″	slope
Alsike clover	S 4	28	3	10′–20′ 10°–20°	5.5–6.5	65	8″	slope
Redtop grass	S 4	28	3	10′–35′ 20°–30°	4.5–6.5	5 N-S 5 E-W	10″	ravine
Legume–grass seeding[4]	S 2	3	4	10′–70′ 27°–35°	5.0–7.0	95	8″–12″	slope, ravine
Legume–grass seeding	S 15	36	4	10′–70′ 24°–40°	4.5–7.0	85	12″–60″	slope, ravine

[1] (P) indicates seedlings planted; (S) indicates seeding.

[2] For spoil refer to Fig. 1.

[3] Plots in which the author conducted soil-treatment experiments have survival percentages recorded for various exposures.

[4] The two-year-old seeding consisted of alfalfa, Kentucky bluegrass, rye grass, smooth brome grass, and white sweet clover. The 15-year-old seeding included those named above plus alsike clover, timothy, and yellow sweet clover. Species were seeded in equal amounts for a total of 20 pounds per acre.

4 to 23 years were studied. Both species were doing very well and ranged up to 48 inches in height. Both food and cover were quite adequate for small game, while an abundance of browse was present for species such as deer. In one eight-year-old seeding, sweet clover still made up 50 per cent of the vegetation. Indications were, however, that sweet clover should usually be reseeded after ten years to retain its dominance and provide adequate habitat, and much sooner if the area is grazed, or if there are other species providing competition.

Alsike clover (*Trifolium hybridum*) was successful on spoils having a *p*H of 5.5, and was quite common as a volunteer. Alsike seedings survived the best and made the best growth in the moist ravines and depressions. Once established in the ravines, it slowly invaded the adjacent slopes of the spoil banks. This species was extremely valuable as food in areas where adequate cover already existed.

Redtop grass (*Agrostis alba*) was fairly successful in the ravines, either when seeded or as a volunteer, but it usually failed to become permanently established on the drier slopes and ridges. Redtop was more successful when used in a mixture of grasses and legumes than when seeded as a pure stand.

The legume–grass seedings included mixtures of alfalfa (*Medicago sativa*), white and yellow sweet clover, alsike clover, smooth brome grass (*Bromus inermis*), rye grass (*Lolium perenne*), Kentucky blue grass (*Poa pratensis*), and timothy (*Phleum pratense*). Two-year-old legume–grass seedings furnished satisfactory habitat which increased in value with age, provided the area was properly managed. Seedings made on ungraded spoil could have been pastured at maximum capacity, without serious harm to the habitat, since the rough areas at the base of the spoil and in the ravines were undisturbed by livestock. Suitable undisturbed cover was present throughout the entire year on these inaccessible areas at the base of the spoil. Dense patches of sweet clover in such areas ranged up to 60 inches in height. Numerous ground dens were also present between the huge boulders at the base of the spoil. Although sweet clover eventually becomes the dominant species and may be undesirable from the standpoint of grazing, it is extremely valuable for the wildlife inhabitants in this region. The heavy stem growth developing the second year, along with volunteer plants present, created excellent habitat for small game.

Shrubs (Table 2).

Scotch broom (*Cytisus scoparius*) proved to be one of the most valuable and most promising species for wildlife food and cover. Scotch broom was successful on both alkaline and acid spoil (*p*H 4.5–7.5), and developed as a clump 65 inches in diameter by the fourth growing season. The species

TABLE 2.—EVALUATION OF SHRUBS

Species	Age of Unit (Years)	Age of Spoil (Years)	Spoil Type	Length and Degree of Slope	*p*H Range	Survival (Per Cent)	Height (Range)	Best Site
Scotch broom	4	28	3	10′–40′ 20°–30°	3.5– 7.5	54 N-S 23 E-W	30″–48″	lower slope, ravine
Indigobush	4	28	3	10′–45′ 20°–30°	4.5– 6.5	100 N-S 92 E-W	36″–68″	ravine, slope
Multiflora rose	4	28	3	10′–40′ 20°–30°	4.5– 6.5	97 N-S 92 E-W	30″–66″	slope
Smooth sumac	4	28	3	20′–30′ 20°–35°	5.0– 6.5	63 N-S 80 E-W	48″–60″	slope
Coralberry	4	28	3	20′–30′ 20°–35°	5.0– 6.5	60 N-S 75 E-W	10″–18″	slope

set seed, and young plants were abundant during the fourth year. Its utility is greatly enhanced since it remains green in southeastern Ohio even during the winter season.

Indigobush (*Amorpha fruticosa*) was extremely successful on coal strip-mined lands, having a survival of 92 to 100 per cent. It reproduced profusely and provided a thicket type of growth. Although it is an excellent plant for gully control and wildlife cover, care should be exercised, however, in the selection of planting sites since it spreads readily to adjacent areas.

Multiflora rose (*Rosa multiflora*) provided excellent cover by the third year, at which time the branches were interlocked when planted 4 feet apart. Multiflora appeared to be more exacting in site requirements than either Scotch broom or indigobush. When planted as a fence within legume–grass seedings, survival and growth were impaired due to competition.

Smooth sumac (*Rhus glabra*) was studied in plantings and as a volunteer. This plant did quite well on both acid and alkaline spoils. Its prevalence as a volunteer indicated that it could be seeded successfully. Smooth sumac growing on strip lands usually bears an abundance of seed annually.

Coralberry (*Symphoricarpos orbiculatus*) on acid spoil and on dry, open sites made very poor growth, although survival was rather high. However, when planted in black locust plantations with an open canopy, growth and survival were fairly good.

Conifers–Mixed Conifers, Mixed Conifers and Hardwoods (Tables 3 and 4)

Ten conifer plantations, each containing a single species, were studied, including red pine, white pine (*Pinus strobus*), short-leaf pine (*P. echinata*), pitch pine (*P. rigida*), and Austrian pine (*P. nigra*). In addition, three plantings of mixed conifers and five mixed conifer–hardwood plantations were surveyed. There were no plantations among the study areas in which jack pine (*Pinus banksiana*) or Scotch pine (*P. sylvestris*) occurred as a single species.

TABLE 3.—EVALUATION OF CONIFERS–SINGLE-SPECIES PLANTATIONS

Species	Age of Unit (Years)	Age of Spoil (Years)	Spoil Type	Length and Degree of Slope	pH Range	Survival (Per Cent)	Height (Range)	Best Site
Red pine	4	28	3	20′–35′ 20°–30°	5.0– 6.5	40 N-S 42 E-W	8″–30″	slope
Red pine	15	34	4	3′–25′ 15°–28°	4.2– 7.2	75	8′–20′	lower slope
Red pine	17	31	3	10′–35′ 5°–25°	4.5– 5.0	6[f]	14′–29′	equal
Red pine	19	21	3	60′–100′ 5°–10°	4.0– 4.5	68	12′–27′	equal
Red pine	23	31	3	20′–45′ 20°–25°	4.0– 6.5	42	16′–32′	lower slope
White pine	2	5	3	10′–40′ 22°–28°	4.0– 6.9	70	8″–38″	slope
White pine	6	32	3	10′–45′ 20°–30°	5.9– 6.0	95	4′–14′	slope
Short-leaf pine	11	18–19	6	25′–55′ 18°–27°	4.0– 7.0	88	5′–18′	slope
Pitch pine	11	18–19	6	25′–55′ 18°–27°	4.0– 7.0	80	5′–18′	slope, ravine
Austrian pine	16	28	3	25′–38′ 15°–28°	4.5– 7.0	10	10′–13′	equal

Those plantations containing a single species generally had good survival, although some red pine had been damaged, in some cases severely, by the European pine shoot moth (*Ryacionia buoliana*). The canopy was usually closed at nine years of age when planted with a 4-foot spacing; the canopy of trees spaced 7 to 8 feet apart did

TABLE 4.—EVALUATION OF MIXED CONIFER–HARDWOOD PLANTATIONS

Species	Age of Unit (Years)	Age of Spoil (Years)	Spoil Type	Length and Degree of Slope	pH Range	Survival[1] (Per Cent)	Height (Range)	Best Site
Mixed conifers–hardwoods	2	7	3	10′–35′ 20°–28°	4.0–5.8	T.P.—75 W.P.—75 W.A.—75 B.L.—95	10″–24″ 8″–10″ 10″–36″ 32″–108″	ravine, slope
Mixed conifers–hardwoods	4	10–12	4	10′–40′ 25°–35°	7.0–7.5	B.L.—90 W.A.—85 T.P.—65 O.O.—85 W.P.—85 R.P.—85	54″–60″ 42″–48″ 12″–18″ 12″–18″ 12″–24″ 12″–24″	slope, ravine
Mixed conifers–hardwood	9	10	4	3′–15′ 15°–28°	5.7–7.0	R.P.—65 J.P.—65 S.L.—65 B.L.—90	4′–10′ 5′–11′ 6′–12′ 10′–20′	pines on slope and in ravine, equal
Mixed conifers–hardwoods	15	33	6	5′–25′ 15°–28°	4.5–7.3	R.P.[2] J.P. S.P. B.L. B.W.	8′–20′ 8′–20′ 8′–20′ 6′–20′ 10′–20′	pines on slope, equal ravine
Mixed conifers–hardwood volunteers	8–24	25	4	20′–40′ 25°–38°	4.0–7.0	B.L.—70 W.A.—70 R.P.—70 S.P.—70 N.S.—70 W.C.—70 R.E.—70	25′–30′ 15′–22′ 8′–12′ 8′–13′ 8′–12′ 18′–20′ 10′–30′	equal
Mixed conifers	9	11	2	6′–35′ 26°–33°	4.0–5.0	R.P.—90 W.P.—90	10″–42″ 10′–42′	equal
Mixed conifers	11	15	4	6′–30′ 5°–15°	6.5–7.5	R.P.—85 S.P.—85 J.P.—85	6′–18′ 5′–16′ 6′–18′	equal
Mixed conifers	15	31–34	6	10′–30′ 15°–23°	4.0–7.5	R.P.—95 S.P.—95 J.P.—95	8′–17′ 10′–25′ 9′–15′	slope

[1] B.L.—Black locust
B.W.—Black walnut (*Juglans nigra*)
J.P.—Jack pine
N.S.—Norway spruce
O.O.—Osage orange (*Maclura pomifera*)
R.E.—Red elm
R.P.—Red pine
S.L.—Short-leaf pine
S.P.—Scotch pine
T.P.—Tulip poplar
W.A.—White ash
W.C.—Wild black cherry
W.P.—White pine

[2] Unable to determine percentage of survival.

not close before 15 years. Earlier cover was provided when spaced 4 feet apart, but little undergrowth had developed. Conifers provided adequate cover during the winter season and also nesting cover for species such as the mourning dove (*Zenaidura macroura*). They are valuable for use on the strip lands of southeastern Ohio where there is little diversity in native cover on the undisturbed land. Shading by volunteer hardwoods created openings which were rapidly invaded by shrubs, vines, and herbaceous plants.

Plantations consisting of a mixture of conifers (Table 4) produced habitat similar to the same species in a pure stand on comparable sites. Growth on the coal strip-land sites was slower than in adjacent old fields, thus producing trees that were more dense and bush-like. This resulted in more protection for game and other species of wildlife. The growth and survival of Norway spruce (*Picea abies*) were comparable to that of the pines.

Mixed conifer–hardwood plantings (Table 4) produced habitat similar to conifers containing native volunteer hardwoods. In general, if the planting contained 25 to 50 per cent of hardwoods, a dense undergrowth developed which greatly increased the amount of food and cover. In such plantations, year-round cover was provided by the conifers while the volunteer shrubs and herbs in the planting, and adjacent croplands provided sufficient food and diversified cover types.

Hardwoods (Table 5)

Hardwood plantations included black locust, red oak, tulip poplar (*Liriodendron tulipifera*), white ash (*Fraxinus americana*), and cottonwood (*Populus deltoides*) usually planted 6 feet apart. Of the entire group of hardwoods, black locust was superior in the development of habitat and in site preparation. This species usually developed a closed canopy by three years and provided some shelter, largely during the spring and summer seasons. At the end of ten years, the black locust plantings contained fairly heavy undergrowth. By the fifteenth year the undergrowth was extremely dense. Many black locust plantings, especially after the tenth year, had been severely damaged by the locust borer (*Megacyllene robiniae*) (Forst). The openings thus created were soon invaded by volunteer shrubs and vines. Ground dens were also quite numerous, averaging slightly over four per acre in one 26-year-old locust plantation.

The other hardwood species studied did not produce desirable habitat as early as the black locust. One 23-year-old red oak plantation was producing acorns; however, there was very little undergrowth present even after 23 years. Since oak, tulip poplar, white ash and other hardwoods are considered more desirable from the standpoint of forestry than is black locust, the latter species because of its site adaptability and usefulness in site preparation, should make up about 25 per cent of the plantation.

Volunteer Trees, Shrubs, Herbs (Table 6)

Coal strip-mined lands having naturally established vegetation ranged in age up to 34 years and included trees, shrubs, vines, and herbaceous species. The percentage of vegetative cover on the spoil surface varied from 20 per cent after five years to 100 per cent by the twenty-fifth year. Trees ranged up to 40 feet in height while undergrowth ranged up to 5 feet on the older strip lands. The rate of plant establishment, density, and species composition of volunteer plant communities was determined by the type and ease of seed dispersal, proximity and composition of adjacent vegetation, and the chemical and physical conditions of the spoil material.

The more common volunteer tree species included wild black cherry (*Prunus serotina*), black willow (*Salix nigra*), sour gum (*Nyssa sylvatica*), American elm (*Ulmus americana*), red elm (*U. fulva*), red maple (*Acer rubrum*), domestic apple (*Malus* spp.), white ash, sassafras (*Sassafras albidum*), sycamore (*Platanus occidentalis*), wild crab apple (*Malus* spp.), bigtooth aspen (*Populus grandidentata*), flowering dogwood (*Cornus florida*), and red-osier dogwood (*C. stolonifera*). One volunteer area consisted of a single species stand of sycamore averaging about 1,500 stems per acre.

The more abundant shrubs and vines included American bittersweet (*Celastrus scandens*), elderberry (*Sambucus canadensis*), greenbrier (*Smilax glauca*), dewberry (*Rubus villosus*), Virginia creeper (*Parthe-*

TABLE 5.—EVALUATION OF HARDWOOD PLANTATIONS

Species	Age of Unit (Years)	Age of Spoil (Years)	Spoil Type	Length and Degree of Slope	pH Range	Survival (Per Cent)	Height (Range)	Best Site
Black locust	2	7	3	10′–35′ 15°–30°	4.0–5.8	98	5′–10′	equal
Black locust	3	5	3	10′–30′ 20°–30°	4.0–6.9	98	4′–12′	equal
Black locust	5	9	4	20′–75′ 25°–34°	7.0–7.5	90	4′–12′	equal
Black locust	9	11	2	6′–35′ 26°–33°	4.0–5.0	95	8′–13′	equal
Black locust	12	18–19	6	10′–45′ 18°–30°	4.0–7.5	80	12′–32′	equal
Black locust	15	31–34	6	5′–25′ 10°–28°	4.0–7.2	75	10′–22′	equal
Black locust	20	21	3	20′–30′ 18°–28°	4.0–5.5	65	10′–35′	equal
Black locust	23	26	4	15′–50′ 20°–25°	4.5–7.3	65	10′–32′	equal
Black locust	25	28	6	30′–35′ 18°–25°	4.5–6.9	60	10′–40′	equal
Black locust	26	31	3	10′–70′ 15°–55°	3.5–7.2	65	6′–30′	equal
Red oak	2	5	3	10′–40′ 22°–28°	4.0–6.9	45	12″–50″	ravine
Red oak	11	13	4	30′–45′ 20°–35°	6.5–7.5	80	2′–10′	lower slope
Red oak	23	31	3	20′–45′ 20°–25°	4.0–7.5	29	16′–36′	lower slope, ravine
White ash	2	5	3	10′–40′ 22°–28°	4.0–6.9	80	1′–9′	ravine, slope
White ash	11	13	4	30′–40′ 20°–30°	4.5–7.5	75	10′–25′	slope, ravine
Cottonwood	11	13	4	35′–45′ 20°–30°	6.5–7.5	80	10′–40′	lower slope
Tulip poplar	2	5	3	10′–50′ 20°–30°	4.0–6.9	65	12″–66″	ravine
Tulip poplar	11	13	4	35′–45′ 20°–30°	4.5–7.5	70	1′–14′	equal
Sweet gum	11	13	4	35′–45′ 20°–30°	4.5–7.5	75	6′–15′	lower slope

nocissus quinquefolia), wild grape (*Vitus labrusca*), poison ivy (*Toxicodendron radicans*), blackberry (*Rubus canadensis*), raspberry (*R. occidentalis*), hazelnut (*Corylus americana*), smooth sumac, and winged sumac (*Rhus copallina*).

Prominent herbaceous species included common ragweed (*Ambrosia artemisiifolia*), giant ragweed (*A. trifida*), orchard grass (*Dactylus glomerata*), smooth brome grass, broomsedge (*Andropogon virginicus*), barnyard grass (*Echinochloa crusgalli*), rye grass, pokeberry (*Phytolacca americana*), shepherd's purse (*Capsella bursa-pastoris*),

TABLE 6.—EVALUATION OF NATURAL REVEGETATION

Volunteer Species	Age of Unit (Years)	Age of Spoil (Years)	Spoil Type	Length and Degree of Slope	pH Range	Spoil Surface Coverage (Per Cent)	Height (Range)	Best Site
Herbaceous-woody	5	5	3	20′–35′ 20°–25°	3.5–6.5	20	10″–50″	ravine, slope
Herbaceous-woody	10	10	3	15′–38′ 20°–25°	3.5–5.5	45	8″–55″	ravine, slope
Herbaceous-woody	10	11	4	10′–50′ 15°–28°	7.0–7.5	10	20″–96″	ravine, lower slope
Herbaceous-woody	10	10	2	10′–45′ 20°–28°	4.0–5.0	40	6″–66″	slope, ravine
Herbaceous-woody (sycamore)	15	11–17	7	6′–40′ 15°–37°	4.5–7.0	85	4′–35′ T[1] 10″–60″U	slope, ravine
Herbaceous-woody	17	17	2	15′–35′ 28°–30°	4.0–6.9	50	3′–25′ T 10″–45″U	slope, ravine
Herbaceous-woody	19	19	6	10′–55′ 20°–30°	4.0–6.5	15	10′–20′ T 10″–96″U	slope
Herbaceous-woody	25	26	4	15′–50′ 20°–25°	4.5–7.3	100	10′–40′ T 10″–60″U	lower slope, ravine
Herbaceous-woody	25	25	2	10′–30′ 20°–28°	5.5–8.0	100	6′–35′ T 8″–60″U	equal
Herbaceous-woody	31	31	3	10′–70′ 15°–55°	3.5–7.2	50	15′–30′ T 8″–30″U	lower slope, ravine
Herbaceous-woody	34	34	6	10′–25′ 15°–32°	4.0–6.5	100	10′–40′ T 6″–60″U	equal

[1] T—Trees. U—Undergrowth: shrubs, vines, and herbaceous species.

lamb's quarter (*Chenopodium album*), white sweet clover, alsike clover, red clover (*Trifolium pratense*), smartweed (*Polygonum pennsylvanicum*), milkweed (*Asclepias syriaca*), timothy, chicory (*Cichorium intybus*), Canada bluegrass (*Poa compressa*), wild carrot (*Daucus carota*), Spanish needles (*Bidens bipinnata*), wild lettuce (*Lactuca canadensis*), and teasel (*Dipsacus sylvestris*).

The wildlife utilization of strip-land areas containing natural vegetation varies. No definite age can be established as to when suitable habitat develops, since the rate of invasion depends upon a number of factors. The value of these volunteers can be greatly implemented by the planting of selected species, especially legumes. Many of these areas developed as open, park-like stands and were frequented by the white-tailed deer (*Odocoileus virginiana*) and the herbaceous-shrub areas provided considerable browse for deer. The bob-white quail (*Colinus virginiana*), cottontail rabbit (*Sylvilagus floridanus*), and woodchuck (*Marmota monax*) also were observed frequently in this type of habitat.

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SUMMARY

In southeastern Ohio, which had approximately 102,706 acres of coal strip-mined lands in 1956, 72 study areas were located to evaluate the survival of 37 species of plants which had been planted mostly for forestry and grazing and which were potentially useful to wildlife.

Of five species of lespedeza surveyed, bicolor and serecia were the most successful and adaptable to the various sites on coal strip lands. Both were growing very well even in fairly acid spoil material. Korean lespedeza did very well when seeded in soil having a high percentage of calcareous materials. Yellow and white sweet clover proved to be very successful on a wide variety of sites and soil conditions. Both species exhibited abundant seed production and a high percentage of seed germination. Alsike clover grew very well in moist ravines and depressions.

Mixed seedings of legumes and grasses, including alfalfa, white and yellow sweet clover, alsike clover, smooth brome grass, Kentucky bluegrass, rye grass, and timothy did well on soils with a *p*H from 4.5 to 7.0. The pasture seedings provided habitat suitable for most game species of southeastern Ohio, especially when smooth brome grass and sweet clover were included.

Scotch broom was the outstanding shrub species and reproduced after the second growing season. Indigobush made excellent growth and had a high survival rate but spread so rapidly in alkaline soils that it proved to be a pest in certain areas. Multiflora rose did not prove adaptable to the poorer sites and could not compete successfully with other species when planted in established meadows.

Conifers, including seven species of pine and Norway spruce, growing in pure or mixed stands, provided cover of considerable value during the critical winter season. Conifers appeared to be most valuable when used in a clump planting or narrow strip and with a spacing of three to four feet.

Black locust was superior to all other hardwood species in the establishment of suitable wildlife habitat. Its adaptability to the various sites present on coal strip lands, its value in site preparation and modification, high survival and rapid growth rates favor its continued use in the reclamation of such lands. Native plant species invaded the black locust plantations very early; and by the tenth to fifteenth year an extremely dense undergrowth had developed.

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THE SMALLMOUTH BASS, *MICROPTERUS DOLOMIEUI*, IN WARM-WATER PONDS

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The smallmouth bass (*Micropterus dolomieui*) is found in both lakes and streams in northern United States and southern Canada; in the glacial lakes where the smallmouth is present (Webster, 1954), it is often associated with rock bass (*Ambloplites rupestris*), perch (*Perca flavescens*), suckers (*Catostomus* spp.), walleyes (*Stizostedion vitreum*), and sometimes northern pike (*Esox lucius*).

South of the border counties of the northernmost tier of states from Minnesota to Maine, the smallmouth is more common in swift clear streams and rivers than in lakes. In these rivers, it is often associated with rock bass, suckers, minnows (Cyprinidae), and sometimes walleyes. This change in habitat from north to south has been explained by the assumption that smallmouths require lower water temperatures and higher oxygen tensions than do largemouth bass (*Micropterus salmoides*), and that these requirements are to be found in streams more often than in lakes and ponds in midcontinental United States (Hubbs and Bailey, 1938).

Because of their importance as game fish, smallmouth bass have been raised in fish hatcheries for many years. A great deal of information on the life history and ecology of this bass is to be found in writings of hatchery superintendents and state fish commissioners, e.g., Osburn, 1923; Beeman, 1924; Hayford, 1924.

Young smallmouths have been stocked widely throughout the United States in many types of aquatic habitats, including ponds. Usually no attempts were made to discover the value of such releases, although in many instances it soon became evident that the young bass had failed to survive. This was particularly true when smallmouth fingerlings were stocked in warm-water lakes and ponds already inhabited by indigenous fishes. Failures were attributed to high water temperatures, muddy lake bottoms, too many competitors, or an overabundance of vegetation (Belding, 1926; Hubbs and Bailey, *op. cit.*). In spite of the fact that the evidence was largely hypothetical, most fisheries people mentally assigned the smallmouth to swift upland streams and clean, cool, sand- or gravel-bottomed lakes.

In 1940, our attention was directed to the smallmouth as a pond fish, when the senior author found several age classes of these bass in an Illinois farm pond (Bennett, 1943). A poison census of this pond (Klein's [Hodge's] Pond north of LeRoy, Illinois) turned up a population of 31 smallmouth bass composed of 16 yearlings, eleven 2-year-olds, two 3-year-olds, and two 4-year-olds. Here was evidence of some reproduction and survival of smallmouths, even though they were in a warm-water pond inhabited by 1,530 green sunfish (*Lepomis cyanellus*), 2,900 black bullheads (*Ictalurus melas*) and 8,677 bluntnose minnows (*Pimephales notatus*). At that time the reproduction of smallmouth bass in this mud-bottomed pond was considered to be unusual because the pond had none of the characteristics of "satisfactory" smallmouth habitat.

In 1947 the senior author decided to study the ecology of smallmouth bass in ponds, in an attempt to discover factors that limited the survival of these fish in this type of habitat.

The first Illinois pond that was stocked by us with smallmouths was a gravel pit pond on the property of David Malcomson near Potomac, Illinois, in 1947. This warm-water introduction proved to be so successful that other ponds in central Illinois were stocked with smallmouths as the ponds became available, until at present 12 are under observation.

Types of Habitat

Several types of aquatic habitats were represented by the 12 ponds stocked with

[1] The Illinois Department of Conservation cooperated in this program in 1955 and 1956 by furnishing financial support for the junior author.

TABLE 1.—SOME CHARACTERISTICS OF THE ARTIFICIAL POND HABITATS[1] THAT MAY HAVE INFLUENCED THE SUCCESS OF SMALLMOUTHS STOCKED IN THEM

Type of Basin Name of Pond	Area, Acres	Max. Depth, Feet	Source of Water	Materials in Basin	Relative Fertility	Year Stocked	Other Fish	Spawning Years
Steep ravine in woods								
Tulagi Pond	0.8	12	surface runoff	clay	below medium	1955	rock bass	none[3]
Ravine below barnyard								
Judkin's Pond	2.0	6	surface runoff	black dirt	very high	1952	none	1954–55
Taylor's Pond	1.0–2.0	6	surface runoff	black dirt	very high	1952[2]	warmouths, red-ears	1952
Eroded ravine								
Sparks's Pond	3.0	9	surface runoff	clay	below medium	1949[2]	warmouths, red-ears	1950 1953–55
Pasture land								
Allerton Lake	14.6	12	surface runoff	clay and black dirt	medium	1951[2]	red-ears, green sunfish, bluegills	1951–56
Old pond in ravine								
Mansion Pond	1.2	9	surface and small spring	black dirt and silt	high	1954	none	none
Abandoned gravel pit								
North Pond	1.0	8	ground water	sand and clay	low	1952	largemouth bass, green sunfish	none
East Pond	1.2	12	ground water	sand and clay	below medium	1953	largemouth bass	none
Gar Pond	0.3–1.0	6–11	ground water	sand and clay	below medium	1955	rock bass, blunt-nose minnows	none[3]
Malcomson's Pond	1.4	12	ground water	sand and clay	below medium	1947	none	1949–56
River flood plain								
Warren's Pond	1.6	7	surface and flowing well	black dirt	very high	1954	none	none[4]
Limestone quarry								
Childer's Lake	11.0	35–40	ground water	rock and clay	low	1953[2]	none	1954–56

[1] All ponds thermally stratified except Judkin's Pond which was only temporarily so.
[2] Stocked with some sexually mature smallmouths.
[3] Smallmouths were immature.
[4] Flooded in 1956.

smallmouth bass (Table 1). The pond basins included eroded gullies in woods, in pasture lands, and below barn lots, flooded gravel pits, a leveed portion of a river flood plain, and a flooded limestone quarry. The ponds varied in size from 0.3 to 14.6 acres and in depth from 6 to 40 feet. The several gravel pits and the stone quarry were filled to ground-water level, and were largely independent of surface-runoff water. Other ponds were supplied with water from surface runoff; in two ponds, surface runoff was supplemented by a spring in one and by a flowing well in the other. Materials lining the pond basins were clay (eroded basins), sand and clay mixed (gravel pits), rocks and clay (quarry), or clay, black dirt, and silt in pond basins not badly eroded.

Because various types of surface materials lined pond basins and watersheds and because some ponds were subjected to fertilization from barnyard runoff, the fertility of the ponds varied, as did the poundages of fish they supported. Judkin's Pond and Taylor's Pond were located adjacent to barn lots and were probably the two most fertile ponds. Judkin's Pond was protected by a low levee from the direct inflow of runoff water from the barn lot, but surface water from a pasture and from a cornfield that received applications of commercial fertilizer could enter the pond after flowing over a protective strip of ungrazed bluegrass. No special drainage channels were developed to by-pass runoff water from the barnyard above Taylor's Pond, and this water flowed almost directly into the pond. A severe winterkill occurred in this pond during January,

1954; but from the fish taken later in wire traps and by hook and line, it was evident that the kill was not complete. However, a complete winterkill did occur in February, 1955, and it became obvious that the usefulness of this pond for any kind of fish was limited until barnyard-wash water could be by-passed around it.

The least fertile of the ponds probably was a newly reflooded limestone quarry. This basin, after quarrying operations were abandoned, contained rock, rubble, and some clay and sand. During quarrying operations, continuous use of several pumps prevented the basin from filling with ground water. Within a few hours after pumping was stopped, seepage water had covered the quarry bottom and was beginning to rise on the steep quarry walls. The quarry is located in the black-soil region of central Illinois, but comparatively little surface runoff is diverted into the quarry lake.

Mansion Pond and Warren's Pond showed indications of high fertility (algae production). Mansion Pond is adjacent to the master house (Allerton House) on the University of Illinois Allerton Estate near Monticello; the pond was probably built at the time the house was built some 55 years ago. A small spring flows from the hillside above the pond, but the flow is so slight as to have little or no influence upon water temperatures. This pond was silted extensively at the upper end, through inwash of soil and debris from the wooded hillside above the pond.

Warren's Pond was built in the flood plain of the Middle Fork of the Vermilion River, southwest of the town of Potomac in east-central Illinois, through the construction of a levee between the natural bank of the valley and the river bank. By reason of its location on lands originally subject to flooding, the pond bottom consisted of black silt.

Of intermediate fertility were the ponds built on pasture lands where overgrazing prior to the construction of the ponds had allowed a considerable loss of topsoil. Tulagi Pond, Sparks's Pond, and Allerton Lake all belonged to this grouping.

Gar Pond, East Pond, and North Pond are small separated units of gravel-digging operations on the farm of William Utterback, southeast of Gibson City. These ponds were fairly infertile and several fish censuses demonstrated that these ponds supported between 50 and 100 pounds of largemouth bass and green sunfish per acre.

Malcomson's Pond near Potomac (a gravel-pit pond) was probably more fertile than the gravel-pit ponds at Utterback's. This may be related to the fact that Malcomson's Pond is located near the base of a hill that is covered with rich topsoil. Little water from this hill runs into the pond directly, but there is probably some seepage.

The range in fertility of the 12 smallmouth bass ponds is probably representative of the ranges to be found in the ponds of the black-soil region of central Illinois.

NESTING OF SMALLMOUTH BASS IN PONDS

Nesting of smallmouth bass was observed in four ponds, and young smallmouths were seen in two others (Table 1). In four of the six remaining ponds, the smallmouths were released as fry or small fingerlings in 1954 or 1955 and, therefore, were sexually immature in 1955; in 1956, no young smallmouths were present, either because the original fish were sexually immature or the young, if produced, were unable to compete with other fish. In the fifth and sixth ponds (East and North ponds), where sexually mature largemouths and smallmouths were present, all of the young observed, or caught on small flies, were largemouths. In the four ponds where smallmouths were seen in the act of digging nests or guarding eggs, the nests were located in black silt, clay, or sand and clay (Malcomson's). These nests were located at water depths of from 2 to 6 feet and were usually about twice as wide (in diameter) as the length of the fish that was guarding them. Consequently, some of the nests were more than 30 inches across.

In Allerton Lake and in Malcomson's Pond, attempts were made annually for a number of years to estimate the success of smallmouth spawning through rough counts of numbers of bass fry. This method was developed for estimating numbers of largemouth fry at Ridge Lake (Illinois) (Bennett, 1954). It was nearly useless for estimating numbers of smallmouth fry or the success of spawning. For example, the numbers of smallmouth fry at Allerton Lake in 1953 appeared to be very low; less than a dozen young were counted around the lake shore

line in early June when the fry should have been readily observed. Yet in early July during a weed-spraying operation, many fingerling smallmouths were present in all parts of the lake, suggesting that the spawn was large and the survival excellent.

Smallmouth bass fry showed very little tendency to remain in compact schools as did largemouth fry; instead, they tended to scatter in the vicinity of the nest and later move about in small groups.

In central Illinois, the smallmouths in ponds spawned about 10 days earlier than did largemouth bass in ponds and about two or three weeks earlier than did the smallmouths inhabiting streams. In most years, pond smallmouths had completed their spawning by the middle of May, whereas pond largemouths did not begin spawning until May 15 or later.

Most, but not all, of the smallmouth fry were black; some resembled the adult smallmouths in coloration. After reaching sizes of 1.0 to 1.5 inches, all of the black fry became much lighter and displayed the typical color pattern of the smallmouth.

Smallmouth fingerlings remained in fairly shallow water in ponds until the end of August, but usually by the middle of September the young of the year had moved out into deeper water.

INTERSPECIFIC COMPETITION

Of the 12 ponds listed in Table 1, smallmouths were alone in five ponds; with warmouths (*Chaenobryttus gulosus*) and redear sunfish (*Lepomis microlophus*) in two; with largemouth bass in one; with rock bass in one; with rock bass and bluntnose minnows in one; with red-ears, green sunfish, and bluegills (*L. macrochirus*) in one; and with largemouths and green sunfish in one.

In all ponds where smallmouths were alone, they appeared to be doing well and apparently were able to find sufficient food in the form of aquatic insects, crayfish, and their own young.

Smallmouth bass were unable to compete with largemouth bass in East Pond and with largemouth and green sunfish in North Pond. They were also becoming reduced in numbers in Judkin's Pond and Taylor's Pond, but organic pollution was believed to be the important limiting factor in both locations.

No one combination of fishes with smallmouths can be shown to be superior to all others. The use of rock bass, or rock bass and bluntnose minnows, was suggested by the occurrence of these species with the smallmouths in local streams. In 1955, neither Tulagi Pond with rock bass, nor Gar Pond with rock bass and bluntnose minnows, had been in operation long enough for the smallmouths to have become sexually mature; but the growth of the smallmouths in these ponds was rapid (Table 2). Red-ear sunfish may be a satisfactory fish to combine with smallmouths because of its being somewhat less prolific than either the bluegill or the green sunfish. In any case, it probably would be of great disadvantage to allow any companion fish with smallmouths to become abundant in a warmwater pond or lake habitat.

GROWTH

Smallmouth bass grow rapidly in warmwater ponds (Table 2) and may become sexually mature when two years of age. Young smallmouths from these experimental ponds had grown to lengths ranging from a low of 3.3 inches to a high of 7.5 inches by the end of the first summer, and from 3.5 to 10.5 inches by the end of the second growing season.

In 1953, scale samples were taken from

TABLE 2.—RANGE OF TOTAL LENGTHS, IN INCHES, OF SMALLMOUTH BASS OF DESIGNATED AGES FROM CENTRAL ILLINOIS WATERS

Water[1]	Age Group 0+	I+[2]	II+	Remarks
Tulagi Pond	—	6.0–7.5	—	—
North Pond	—	5.9–8.7	—	—
East Pond	—	5.5–7.5	9.0–15.5	—
Gar Pond	5.0–7.5	—	—	Sept.
Judkin's Pond	—	—	10.0–14.0	—
Taylor's Pond	—	5.9–6.3	—	—
Sparks's Pond	—	4.0–7.0	8.0–10.0	
Warren's Pond	—	5.5–9.8	—	Sept.
Allerton Lake	—	7.0–8.0	10.0–11.0	July First year class in lake
Allerton Lake	—	3.5–4.1	6.0–9.5	Second and third year classes

[1] No data are available on bass in Mansion Pond.
[2] Collections were made in May or June unless specified.

most of the 347 bass caught by fishermen at Malcomson's Pond. These scales were "read," and ages assigned to each fish. As may be seen in Table 3, these smallmouths averaged 5.3 inches in total length at the end of the first growing season, 9.3 inches the second, 11.1 inches the third, 12.2 inches the fourth, and 14.3 inches the fifth. This growth is somewhat more rapid (Table 3) than that of smallmouths indigenous to Jordan Creek in central Illinois (Durham, 1955).

TABLE 3.—AVERAGE GROWTH OF SMALLMOUTH BASS IN MALCOMSON'S POND AND JORDAN CREEK

Water	Average Total Length in Inches at End of Named Growing Season					
	1st	2nd	3rd	4th	5th	6th
Malcomson's Pond	5.3	9.3	11.1	12.2	14.3	—
Jordan Creek	3.3	6.3	9.5	11.4	12.8	13.9

The largest smallmouth bass were taken from Allerton Lake and Judkin's Pond, but no fish collected to date (April, 1957) has exceeded 3.5 pounds in weight.

POPULATION DYNAMICS

More information on the population dynamics of smallmouths was available from Allerton Lake and from Malcomson's Pond than from the other experimental ponds. Not only have the bass in these ponds been studied for a period of several years, but one or more complete censuses were made of their fish populations.

Allerton Lake.—This artificial lake of 14.6 acres was stocked in May of 1951 with 16 adult and 16 yearling smallmouths. In the fall of 1952 (October), the lake was drained and a census was made of the smallmouth bass and other fish present (Table 4). After 17 months, including two spawning seasons, the smallmouth bass population consisted of 15 of the original 32 fish released in the lake, 294 yearling smallmouths, and 2,660 smallmouth fingerlings, making a total of 2,969 fish weighing 426.8 pounds.

Other fish present were 11,780 green sunfish, 7 largemouth bass, 1 black crappie (*Pomoxis nigromaculatus*), 5 bluegills, and 1 golden shiner (*Notemigonus crysoleucas*).

TABLE 4.—CENSUS OF THE FISH IN ALLERTON LAKE, 4-H CLUB CAMP NEAR MONTICELLO, ILLINOIS, SEPTEMBER 26–OCTOBER 3, 1952

Kind	Number	Total Weight, Pounds	Average Weight, Pounds	Per Cent of Total Weight
Smallmouth Bass				
Original stock	15	42.5	2.84	—
1951 brood	294	171.6	0.58	—
1952 brood	2,660	212.7	0.08	—
Total	2,969	426.8	—	31.0
Green Sunfish	11,780	942.3	0.08	68.6
Largemouth Bass				
Original stock	2	3.2	2.47	—
1952 brood	5	0.8	0.16	—
Total	7	4.0	—	0.3
Black Crappie	1	0.6	0.55	—
Bluegills	5	0.4	0.08	—
Golden Shiner	1	tr.	0.01	0.1
Grand total	14,763	1,374.1		100.0
Per acre	1,011	94.1		

It is probable that the largemouth bass, the crappie, and the bluegills were stocked by "helpful" fishermen, although it is illegal in Illinois for anglers to move fish from one body of water to another. The green sunfish were believed to have been present in underground drain tiles having outlets within the lake basin. At the time the outlet valve at the dam was closed, no water was flowing through the lake basin and no pools of standing water were visible. However, enough green sunfish may have been present in the underground tiles in 1950 to produce the large population found in the 1952 census. The total poundage of bass and sunfishes supported by Allerton Lake amounted to less than 100 pounds per acre, suggesting that the population had had insufficient time to expand to the maximum weight of fish that the lake would support.

About 700 of the smallmouth bass from Allerton Lake were wintered in Arrowhead Pond near Allerton Lake; and on March 19, 1953, 697 smallmouths were returned to the refilled basin of the larger lake. These fish consisted of 3 original fish, 155 fish of the 1951 brood, and 539 fish of the 1952 brood. On May 15, 1953, 53 red-ear sunfish were released in Allerton Lake. No censuses of the

fish in Allerton Lake were made in 1954 and 1955.

Fall drawdowns of the lake level were made in September of both 1954 and 1955. The 1954 drawdown reduced the depth of the lake at the gate valve from 13.7 to 7.3 feet and the surface area from 14.6 to about 7.5 acres. The lake refilled over the winter of 1954–55, and the spawn of smallmouths during May of 1955 appeared to be the largest recorded.

A drawdown of similar extent was made in early September of 1955 and the water was held at a low level throughout the fall months. This prolonged low water level allowed the germination of seeds and the growth of curly-leaved pondweed (*Potamogeton crispus*) in the deeper parts of the lake. When Allerton Lake was gradually refilling during the spring of 1956, the curly-leaved pondweed grew with the rising water and, because of its start during low water, was able to form extensive dense stands in water 8–12 feet in depth where the plant had never been before. In contrast, only sparse vegetation was present in the strip of shallow water parallel to the shore where the exposed bottom dried out during the period of drawdown in 1955.

The extensive beds of pondweed offered excellent protection for young green and red-ear sunfishes spawned during the summer of 1956, and even a drawdown of the lake level of 6.5 feet in September of 1956 did not expose these sunfishes to predation, although thousands of small green sunfish (but not red-ears) were stranded in the submerged vegetation that was exposed by the receding water.

Between October 8 and 13, 1956, Allerton Lake was drained completely and a census made of the fish (Table 5). A Wolf-type weir (Wolf, 1951) built below the lake outlet was covered with copper screening to make possible the capture of fishes of all sizes. None of the smallmouth bass belonged to the 1956 year class or brood, although a moderately successful spawn was observed in May. Apparently the green sunfish had limited the survival of the smallmouth fingerlings. A length-frequency distribution of the 148 smallmouths is shown in Table 6. These fish have been arbitrarily separated into year broods on the basis of length distribution and observed growth in other waters. The 15 fish in the 1951 year class (first brood spawned in the lake) ranged in total length from 16.5 to 18 inches and in weight from 2.7 to 3.5 pounds.

TABLE 5.—CENSUS OF FISH IN ALLERTON LAKE, 4-H CLUB CAMP NEAR MONTICELLO, ILLINOIS, OCTOBER 8–13, 1956

Kind	Number	Total Weight, Pounds	Average Weight, Pounds	Per Cent of Total Weight
Smallmouth Bass				
1955 brood	29			
1954 brood	71			
1953 brood	17			
1952 brood	16			
1951 brood	15			
Total	148	126.9	0.85	4.1
Red-ear Sunfish				
3.5–6.5 in.	16,600	664.8	0.04	
1.0–3.4 in.	40,600	402.0	0.01	
Total	57,200	1,066.8	0.02	34.7
Bluegills[1]				
4.5–6.5 in.	2,253	202.9	0.09	
6.6–8.0 in.	19	5.8	0.31	
Total	2,272	208.7		6.8
Green Sunfish				
3.5–6.5 in.	5,960	418.6	0.07	
1.0–3.4 in.	121,900	1,215.0	0.01	
Total	127,860	1,633.6		53.1
Red-ear × green hybrids				
1956 brood	3,320	33.0	0.01	1.1
Miscellaneous				
Black bullheads	4	1.7		
Common suckers	3	3.3		
Chub sucker	1	0.4		
Misc. minnows	5	0.2		0.2
Total	13	5.6		
Grand total	190,813	3,074.6		100.0
Per acre	13,052	210.3		

[1] Includes about 20 bluegill × green sunfish hybrids.

While it was impossible to obtain a creel record of the fishermen's catch at Allerton Lake, there were a number of reports of catches of large smallmouths from this lake prior to our October draining census. The population of smallmouths in Allerton was definitely "on its way out." The failure of the 1956 year class must be attributed to the great expansion of green sunfish.

In 1956 the lake was supporting 210.3 pounds of fish per acre in contrast to the 1952 population of 94.1 pounds per acre.

TABLE 6.—LENGTH-FREQUENCY DISTRIBUTION OF SMALLMOUTH BASS TAKEN IN THE FISH CENSUS OF ALLERTON LAKE, OCTOBER 8–13, 1956

Total Length, Inches	Number of Fish	Estimated Year Class
6	2	
6.5	4	
7	7	1955
7.5	9	
8	4	
8.5	5	
9	7	
9.5	10	
10	18	1954
10.5	15	
11	11	
11.5	8	
12	5	
12.5	6	
13	3	1953
13.5	3	
14	1	
14.5	8	
15	3	1952
15.5	2	
16	2	
16.5	4	
17	5	1951
17.5	3	
18	3	
	148	

Further comparisons of the two censuses show 203 smallmouths per acre weighing 29.2 pounds in 1952 in contrast to 10 smallmouth bass per acre weighing 8.7 pounds in 1956; and 807 green sunfish per acre weighing 64.5 pounds in 1952 in contrast to 8,758 per acre weighing 111.9 pounds in 1956.

Following the 1952 census, all undrained water pockets and tile outlets within the lake watershed were treated with emulsifiable rotenone to kill any fish remaining. The effort was futile, and after the 1956 census it was believed impossible to eliminate the green sunfish from this lake unless it could be accomplished through predation on them by a large population of largemouth bass. The smallmouth bass were obviously unable to compete with the green sunfish in Allerton Lake.

Malcomson's Pond.—The history of the smallmouth bass population of this 1.42-acre gravel-pit pond is of particular interest and importance because (1) it has contained no fish other than smallmouths and spotted bass (*Micropterus punctulatus*) during the 9-year period of its existence, and (2) there is a complete record of the catch of bass for this period.

Malcomson's Pond was stocked on September 3, 1947, with 74 spotted bass and 13 smallmouth bass fingerlings, all seined from the Middle Fork of the Vermilion River at a location within one-fourth mile from the pond. No fishing was allowed in the pond in 1948, but in 1949 a limited catch of 31 bass weighing 25 pounds was made. In 1950, an additional 20 bass weighing 29.2 pounds were taken.

The bass were first observed to spawn in 1949, and most of the young appeared to be smallmouths; a good spawn was observed in 1950, and in early 1951 a large population of bass (mostly smallmouths) was present.

Fishing pressure was increased in 1951 and throughout the next four years the yield of bass ranged from 158 fish in 1951 to 347 in 1953, representing annual yields of 78.0 and 123.0 pounds of bass per acre (Table 7). These yields of bass were higher than any previously recorded for either largemouth or smallmouth bass.

TABLE 7.—HOOK-AND-LINE YIELDS OF SMALLMOUTH BASS[1] FROM MALCOMSON'S POND (1.42 ACRES) DURING THE FISHING SEASONS FROM 1951 TO 1954, INCLUSIVE

Year	Number of Fish	Total Weight, Pounds	Pounds per Acre
1951	158	110.8	78.0
1952	254	170.1	119.9
1953	347	174.7	123.0
1954	258	115.4	81.3

[1] Ten spotted bass weighing 12.3 pounds were caught in 1951, 2 weighing 1.05 pounds in 1952, and 2 weighing 1.0 pound in 1953.

In 1954, an attempt was made to record accurately the time spent in fishing, in order to measure the fishing return per unit of effort. The pond was visited by 48 fishing parties composed of from 1 to 5 fishermen; the length of time each fished averaged about 2.5 hours. The average catch per

fisherman-trip was 5 smallmouth bass weighing 2.5 pounds, or an average rate of catch for the entire season of approximately a pound of bass per hour of fishing. In the experience of the authors, such a rate of catch for either smallmouth or largemouth is very unusual. For comparison, an analysis of the April to June catch that was made prior to the final fish census of 1955 showed that fishermen had visited the pond on 35 occasions in groups of from 1 to 5 men and had made an average catch of 5 smallmouth bass per man-trip having a total weight of 1.95 pounds, a catch as large in number but somewhat smaller in weight than that made in 1954.

On June 8, 1955, the pond was treated with rotenone, and a census made of the remaining smallmouth bass. At this time, the water had been lowered by pumping and that remaining in the pond basin was so clear that dead fish could be seen on the pond bottom in the deepest water. For this reason, it was believed that the pickup of bass larger than 1.5 inches (young of the year) was nearly complete. The population consisted of an estimated 5,000–6,000 young smallmouths about 1 to 1.5 inches long. No attempt was made to count these, because in a poisoning operation these small fish die first and they are fed upon by larger fish and other aquatic predators. Larger bass in the census consisted of 243 smallmouths ranging in length from 4 to 8.5 inches and 49 fish ranging in length from 10 to 15 inches. The combined weight of the two length groupings of larger bass was 74.3 pounds or 52.3 pounds per acre. No weight estimate was included for the young-of-the-year bass. No spotted bass were present.

Scales were collected from a representative sample of the bass taken in the poison census. Fish in the 5- to 8.5-inch-length range belonged to year classes I and II; these fish at the time of capture were 13 and 25 months old, respectively. Year classes represented in the 10- and 15-inch-length grouping were III, IV, and V (only two fish in V), or fourth-, fifth-, and sixth-summer fish.

In a study of the length-frequency distribution of the bass caught by fishermen in the years 1951 to June 6, 1955, inclusive (Table 8), and the growth rates of smallmouths in various years at Malcomson's Pond, it appeared that the crop of fish taken by anglers in any fishing season was largely dependent upon the survival of adequate numbers of young smallmouths two years before, e.g., the failure of a year class would be reflected in a much reduced catch in the second summer following the year of the failure.

The yield of smallmouth bass from Malcomson's Pond is probably unique in one other respect, namely, in its relationship to the standing crop that the pond will support. At the beginning of the 1955 fishing season, Malcomson's Pond must have contained the bass caught by fishermen during April and May plus the bass taken in the census of June 8, or a total of 472 fish, exclusive of an unknown number of fingerling bass that may have been eaten by larger bass during the spring of 1955. The part of the population caught by fishermen during April and May weighed 68.1 pounds (approximately 48.0 pounds per acre) and the part taken in the final census weighed 74.3 pounds (52.3 pounds per acre) making the total weight of 142.4 pounds or 100.3 pounds per acre. This poundage may be more than the standing crop that the pond will support at any given time because the fish that escaped the fishermen during April and May could be expected to add flesh during that period. On the basis of catches made during the seasons of 1952 and 1953 of 119.9 and 123.0 pounds per acre, respectively, it seems safe to assume that there may be an annual replacement of fish flesh which in this instance exceeds the standing crop that the pond will support. This annual "turnover" is about twice the potential for waters in the region of central Illinois, as estimated by Thompson (1941).

FEEDING HABITS AND FISHING

These investigations furnished some evidence that smallmouths in ponds by themselves were more easily caught on artificial flies and other artificial surface lures than were smallmouths in ponds with other kinds of fishes. On the basis of general observations at Malcomson's Pond and some subsurface observations by the junior author at Childer's Lake, smallmouths by themselves in ponds look to the pond surface for food, and are more in the habit of feeding upon adult aquatic insects and terrestrial insects

TABLE 8.—LENGTH–FREQUENCY DISTRIBUTION OF SMALLMOUTH BASS TAKEN BY ANGLERS EACH YEAR FROM MALCOMSON'S POND NEAR POTOMAC, ILLINOIS, 1949 TO JUNE 6, 1955, INCLUSIVE, AND SMALLMOUTH BASS TAKEN IN A COMPLETE CENSUS OF THE POND JUNE 8–13, 1955. ESTIMATES OF WEIGHT OF ANNUAL YIELDS AND YIELDS IN POUNDS PER ACRE ARE SHOWN

Total Length, Inches	1949	1950	1951	1952	1953	1954	1955		
							April 11–June 6	Poison Census, June	Total Fish
4	—	—	—	—	—	—	—	2	2
½	—	—	—	—	—	—	1	7	8
5	—	—	—	—	—	1	2	20	22
½	—	—	—	—	—	5	4	29	33
6	—	—	—	1	—	17	14	38	52
½	—	—	—	2	—	2	23	58	81
7	—	1	1	5	2	2	43	37	80
½	—	—	1	2	11	—	13	29	42
8	—	—	3	2	18	1	13	16	29
½	—	—	9	1	32	2	1	7	8
9	—	—	20	11	56	46	1	—	1
½	—	—	28	20	23	59	1	—	1
10	1	1	27	41	37	32	4	2	6
½	1	—	11	17	42	25	6	2	8
11	4	—	21	31	44	18	14	6	20
½	—	—	2	39	21	25	4	15	19
12	3	—	8	43	37	15	16	10	26
½	3	2	4	11	13	6	12	5	17
13	5	1	1	9	8	1	3	5	8
½	4	2	2	6	—	1	—	2	2
14	—	5	3	2	2	—	2	—	2
½	1	1	2	2	—	—	2	1	3
15	—	2	5	1	—	—	1	1	2
½	1	1	1	—	—	—	—	—	—
16	—	2	—	1	1	—	—	—	—
½	—	1	1	1	—	—	—	—	—
17	1	1	1	2	—	—	—	—	—
½	—	—	1	—	—	—	—	—	—
18	—	—	2	1	—	—	—	—	—
½	—	—	2	—	—	—	—	—	—
19	—	—	2	1	—	—	—	—	—
Totals	24[1]	20	158[2]	254[3]	347[4]	258	180	292	472
Est. total pounds	24.3	29.2	110.8	170.1	174.7	115.4	68.1	74.3	142.4
Pounds per acre	17.1	20.6	78.0	119.9	123.0	81.3	48.0	52.3	100.3

[1] Includes 7 spotted bass weighing 4.77 pounds.
[2] Includes 10 spotted bass weighing 12.34 pounds.
[3] Includes 2 spotted bass weighing 1.05 pounds.
[4] Includes 2 spotted bass weighing 1.00 pound.

that fall into the water than are smallmouths that have a food source of minnows and the young of other fish. At Malcomson's Pond it was not at all unusual to see smallmouths jumping for damsel flies and dragonflies, while these insects were depositing eggs or flying about close to the pond surface. At Childer's Lake, smallmouths were usually in shallow water along the steep quarry banks in position to strike at any live insect or other small animal that fell from the edges of the land above the quarry. In contrast, the smallmouths inhabiting Allerton Lake, along with red-ears and green sunfish, seldom were observed to feed at the lake surface and most of them were caught by fishermen using underwater plugs or live minnows.

The unusual rate of catch of smallmouths made at Malcomson's Pond in 1954 of 2 bass (or one pound of bass) per hour of fishing was believed to be related to the surface feeding habits of these fishes. A similar illustration may be taken from a record of fishing at Childer's Lake in 1956 that was made when smallmouth bass were collected for stocking a newly renovated pond. During 22 man-hours of fishing from July 5 to 11, inclusive, the authors caught 192 smallmouth bass at an average rate of 8.7 fish per man-hour. These fish were relatively small (Childer's Lake was stocked in 1953 with 12 adult and 500 fingerling smallmouths), ranging in size from 5.5 to 11.0 inches and averaging about 8.0 inches. Almost all of them were caught on small floating chartreuse-colored "poppers."

Childer's Lake had been fished by members of the Fairmount Quarry Fish–Game Club in the fall of 1955, but the lake was not opened to fishing in 1956 until August, after our collection was made.

ACKNOWLEDGMENTS

All of the ponds used for smallmouth studies were owned by individuals, clubs, or the University of Illinois (Allerton Lake and Mansion Pond). We are indebted to these pond owners for the use of their ponds, and for their cooperation in this investigation. Pond owners David Malcomson and William Utterback (North Pond, East Pond, Gar Pond) also collected creel data and scale samples for growth studies, and assisted us in many other ways, even allowing us to poison smallmouth populations when we considered a fish census necessary to furnish standing crop data. Fay H. Root, in charge of Camp and Park Management for the University of Illinois Allerton Estate, and his staff were very helpful in many aspects of the smallmouth studies in ponds on the Allerton Estate. Leonard Durham aged the fish represented by the scale collection of 1953.

SUMMARY

Smallmouth bass were able to live in 12 ponds representing most types of warm-water pond habitats located at or north of the latitude of central Illinois. They were observed to reproduce successfully in one-half (6) of these ponds during and prior to the summer of 1956. Failure of smallmouths to reproduce in the other 6 ponds was believed to be related to (1) an absence of sexually mature fish or (2) their inability to compete successfully with largemouth bass and green sunfish.

Most successful smallmouth bass ponds were those in which smallmouths were by themselves or with some other fish less prolific than bluegills, green sunfish, or black bullheads.

A population of smallmouths in one lake (14.6 acres) expanded from 32 fish to 2,969 in two growing seasons. In the next four growing seasons, this population dropped from 697 bass returned following the 1952 census to 148 fish; the reduction was due to angling and failure of reproduction due to excessive competition with sunfish.

A 1.4-acre gravel-pit pond produced hook-and-line yields of smallmouth bass ranging from 78 to 123 pounds per acre during the fishing seasons of 1951–54, inclusive. These fish were caught at an average rate of about two fish or one pound per hour. When the pond was censused, it contained 52.3 pounds of bass per acre. This suggested the possibility of an annual turnover of more than 100 per cent of the standing crop.

Smallmouths living alone in ponds became habitual surface feeders and for this reason were more easily taken on artificial flies and other surface lures than were smallmouths living in ponds with other kinds of fishes.

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FOOD HABITS OF THE COYOTE IN MISSOURI[1]

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The coyote (*Canis latrans*) long has been a controversial figure in the minds of farmers, game managers, sportsmen, and legislators in Missouri. The animal was given its specific name by Thomas Say, a member of Long's expedition to the Rocky Mountains in 1823, just two years after the state of Missouri was admitted to the Union. By 1825, state law permitted the payment of bounties on predatory animals, which included the wolf, coyote, and bobcat, because of their alleged depredations on livestock and poultry (Sampson and Bennitt, 1947). Since then the coyote (prairie wolf or brush wolf) has been considered an outlaw.

The coyote dwells primarily in prairie or brushland along the edge of timber and in open farmlands. It is found throughout Missouri, except for the extreme southeastern lowland counties, and is most commonly observed in the western and northern parts of the state (Schwartz and Schwartz, 1954).

Coyote density figures for Missouri prior to 1935 are essentially lacking. The most reliable density data come from coyote bounty records compiled for the past 20 years (Sampson, 1956). Such information cannot be used to appraise abundance, but indicates trends. Bounty records show an ever-increasing kill of coyotes, with minor fluctuations, from 1936 until 1947. The trend weakened but remained high through 1952, after which a steady annual decline in harvest occurred.

These data also show that this study of coyote food habits was conducted during the years of greatest recent coyote abundance in Missouri. Theoretically, at least, these years should also have been the period when coyotes exerted the greatest pressure upon wildlife, domestic livestock, and poultry.

TECHNIQUES OF STUDY

This investigation was begun during 1947, as a continuing study of several years' duration, with three objectives in mind: (1) to learn the general feeding habits of coyotes in Missouri, as a basis for maintaining or revising present predator-control policies; (2) to learn the extent and effect of predation upon managed wildlife species; and (3) to learn the seasonal extent of predation upon livestock and poultry in Missouri.

It was originally planned to collect predator stomachs from state game refuges. However, in 1949 state-wide collection was begun. Materials for preservation of predator stomachs were supplied to some 50 county clerks who paid bounties on coyotes, approximately 130 cooperating hunters and trappers, and Conservation Commission personnel. This report includes data from all

[1] A contribution from Pittman-Robertson Project, Missouri 13-R.

[2] The writer wishes to acknowledge the cooperation of approximately 130 hunters and trappers, 50 county clerks, Conservation Commission personnel, particularly refuge managers, conservation agents, biologists, and field-service agents, who assisted with the collection of materials for this investigation. Had it not been for their untiring efforts, this study would have been impossible. Thanks also are due Dr. P. W. Frank, University of Missouri, for statistical analyses.

sources: refuge personnel of the Conservation Commission, county clerks, hunters and trappers, conservation agents, and other interested individuals.

Study materials were preserved in wide-mouthed quart or half-gallon fruit-jars that contained a 10-per-cent formaldehyde solution. Collected materials were picked up periodically by the investigator for complete analyses. In general, the analyses followed standard food-habits study procedures (Martin, 1949). The stomachs were opened, and contents washed and partially dried. The food items then were separated according to kind, identified, and the volume of each was ascertained.

Identification of food items was aided by use of a 15× binocular dissecting microscope. A compound microscope with 440× magnifications also was used, when needed, to check identifications of hair and feathers. Other equipment included: enamel pans, Petri dishes, scalpel, forceps, graduated glass cylinders, wood packing rods, and hair, skull, and seed reference collections.

REVIEW OF LITERATURE

Coyote foods and feeding habits are well documented for the western and west-central states where these animals are most abundant. Data for the eastern part of the range are more limited. Sperry (1941) compiled data from the analyses of 8,263 stomachs that contained a measurable amount of food. These data, based mostly upon animals collected from the western states, showed the diet to consist of 98.25 per cent animal and 1.75 per cent vegetable foods. Principal foods were shown to be: rabbits, one-third; carrion, one-fourth; rodents, nearly one-fifth; and livestock, one-eighth of the diet. Deer, birds, insects, and other foods were taken in smaller amounts. Plant foods were mainly fruits and grass.

Ferrel, Leach, and Tillotson (1953) found from the examination of 2,222 stomachs in California that coyotes ate 96 per cent animal and 4 per cent plant foods. Rodents and rabbits were most important. Similar findings were reported by Tiemeier (1955) from 871 stomachs in Kansas; by Fichter, Schildman, and Sather (1955) from 747 stomachs from Nebraska; and by McLean (1934) and Dixon (1925) from 240 and 185 coyote stomach examinations, respectively, from California.

Murie (1935), studying the coyote in Jackson Hole, Wyoming, concluded that 70.29 per cent of its feeding was economically beneficial, 18.22 per cent neutral, and only 11.49 per cent economically destructive. McKean (1948) also concluded, after examination of 585 carnivore stomachs in North Dakota, that no predatory species was more than moderately detrimental to game or domestic animals in winter. In California, Bond (1939) reached essentially the same conclusion. Horn (1941), on the other hand, believed that coyotes in certain areas of California played a measurable part in regulating the numbers of deer, but did not control the rodent–rabbit populations. Presnall (1953) is in agreement with Horn (*op. cit.*) on the latter point. He maintained that coyotes alone do not and cannot control rabbit and rodent populations, because rodents and rabbits simply outbreed coyotes. Leach and Frazier (1953) concluded that quail are minor prey species for coyotes, and that control of mammalian predators is of doubtful value even in quail concentration areas. Shindorf (1953) cited a change in attitude among Colorado ranchers following extensive predator-control operations: rodents and other small mammals increased rapidly to destructive numbers, with the result that all further control of coyotes and most other predators was barred from the Toponas Grassland Protective Association lands. Nagel, Sampson, and Brohn (1955) and Tiemeier (*op. cit.*) have expressed recent views of coyote feeding habits and control when they conclude that annual fluctuations in feeding habits follow abundance of prey species. The wholesale elimination of coyotes is not desired, but control of individual offenders is recommended where depredation on domestic animals occurs. In Missouri, this is accomplished through the extension predator-control program (Sampson and Brohn, 1955).

Several cases are on record to show that crippled or old animals are the most destructive to agricultural interests. Typical of these are Sperry (1939) and Hawbecker (1939), who reported on the activities of peg-leg or crippled coyotes. The Criddles (1923) found that livestock killing often could be traced to an old coyote that had

found domestic animals to be more easily secured than wild ones.

There are other reports of unusual coyote feeding habits. Presnall and Wood (1953) cited a case where a female and seven pups apparently lived largely upon sage grouse (*Centrocercus urophasianus*). Cahalane (1947) described how three coyotes killed a mule deer (*Odocoileus hemionus*); and Grimm (1940) reported observations of coyotes catching and feeding upon trout and crayfish.

RESULTS AND ANALYSES

The results of my examination of 770 coyote stomachs are shown in tabular form in Tables 1–3. Data from an additional 326 coyote scat analyses comprise Table 4. Data are presented as prey species, or foods eaten, with percentages by occurrence and volume of each identified food item. All items identified in the stomach contents are listed in Table 1, except cloth (trap-pan covers) and plant debris (leaves, stick, bark), which were assumed to have been taken by trap-bound animals and, therefore, were omitted from the food tabulations.

Most of the 770 coyote stomachs used in this study were collected in Missouri from 1948 through 1953. An unknown number of samples came from adjoining states during the first two years of collection, but were taken by Missouri hunters in nearby Kansas and Nebraska. Because agricultural practices, topography, and habitat conditions were so nearly the same throughout the hunted area of northwestern Missouri, eastern Kansas and Nebraska, all stomachs were considered to be typical of northwestern Missouri.

TABLE 1.—FOODS OF 770 COYOTES IN MISSOURI, 1948–54

Food Item	Per Cent by Occurrence[1]	Volume	Food Item	Per Cent by Occurrence[1]	Volume
RABBITS	(55.3)	(53.7)	OTHER MAMMALS (Continued)		
Cottontail (*Sylvilagus floridanus*)	53.9	51.9	Ground squirrel (*Citellus franklinii*)	0.1	0.2
Jackrabbit (*Lepus* spp.)	1.4	1.8	Skunk (*Mephitis mephitis*)	0.5	0.2
POULTRY	(15.8)	(11.3)	Short-tailed shrew (*Blarina brevicauda*)	0.3	0.1
Chicken (*Gallus gallus*)	14.2	10.3	Spotted skunk (*Spilogale interrupta*)	0.1	tr.
Turkey (*Meleagris gallopavo*)	1.3	0.7	Least shrew (*Cryptotis parva*)	1.2	tr.
Goose (*Anser anser*)	0.3	0.2	Mole (*Scalopus aquaticus*)	0.1	tr.
Guinea fowl (*Numida meleagris*)	0.1	tr.	CARRION	8.6	5.8
LIVESTOCK	(13.8)	(8.9)	INVERTEBRATES (at least 18 species)	(7.4)	(0.8)
Calf (*Bos taurus*)	3.5	3.4	Short-horned grasshoppers (Acrididae)	5.8	0.6
Pig (*Sus scrofa*)	6.1	3.1	Walking-sticks (Phasmidae)	0.4	0.1
Sheep (*Ovis aries*)	3.9	2.1	Long-horned grasshoppers (Tettigoniidae)	2.1	0.1
Goat (*Capra hircus*)	0.6	0.4	Other insects, crayfish, spiders, and centipedes, each in "trace" amounts		
MICE AND RATS	(32.1)	(8.7)	BIRDS	(6.2)	(0.5)
Meadow mouse (*Microtus ochrogaster*)	19.4	4.4	Quail (*Colinus virginianus*)	1.4	0.2
Cotton rat (*Sigmodon hispidus*)	3.2	1.7	Birds, unclassified	1.7	0.1
Lemming mouse (*Synaptomys cooperi*)	4.2	1.5	Crow (*Corvus brachyrhynchos*)	0.4	0.1
White-footed mouse (*Peromyscus* sp.)	5.3	0.4	Songbirds, unclassified	2.7	0.1
Pine mouse (*Pitymys nemoralis*)	0.4	0.2	UNDETERMINED ANIMAL MATTER	0.9	0.4
Barn rat (*Rattus norvegicus*)	0.4	0.2	SNAKE, UNCLASSIFIED	0.1	tr.
House mouse (*Mus musculus*)	2.2	0.2	PLANT FOODS	(19.7)	(2.0)
Harvest mouse (*Reithrodontomys* sp.)	1.6	0.1	Persimmon (*Diospyros virginiana*)	7.3	1.4
Mouse, unclassified	1.3	tr.	Grass and sedge leaves	10.6	0.3
OTHER MAMMALS	(11.7)	(7.5)	Corn (*Zea Mays*)	1.4	0.2
Raccoon (*Procyon lotor*)	1.3	1.8	Pear (*Pyrus communis*)	0.6	0.1
Deer (*Odocoileus virginianus*)	2.9	1.6	24 other plant foods, each in "trace" amount		
Woodchuck (*Marmota monax*)	2.1	1.3	MISCELLANEOUS		
Fox squirrel (*Sciurus niger rufiventer*)	1.7	0.8	Garbage	0.3	0.1
Opossum (*Didelphis marsupialis*)	0.9	0.7	Leather	0.6	0.1
Gray squirrel (*Sciurus carolinensis*)	0.8	0.3	Paper, gauze, rubber, and string, each in "trace" amount		
Gray fox (*Urocyon cinereoargenteus*)	0.1	0.2			
House cat (*Felis domestica*)	0.3	0.2			

[1] These percentages have been carried one digit past the decimal point for comparative purposes and not to indicate that this digit is a significant one.

TABLE 2.—PRINCIPAL FOODS OF THE COYOTE IN MISSOURI, BY YEAR

	Percentages by Occurrence and Volume											
Fiscal Year	1948–49		1949–50		1950–51		1951–52		1952–53		1953–54 and Later	
No. Stomachs Examined	114		254		214		83		55		50	
	Occ.	*Vol.*	*Occ.*	*Vol.*	*Occ.*	*Vol.*	*Occ.*	*Vol.*	*Occ.*	*Vol.*	*Occ.*	*Vol.*
RABBITS AND HARES	(67)	(61.2)	(59)	(58.7)	(57)	(54.4)	(41)	(41.4)	(33)	(19.2)	(54)	(44.2)
Cottontail	64	59.4	57	56.7	56	52.5	39	38.4	33	19.2	54	44.2
Jackrabbit	3	1.8	2	2.0	1	1.9	2	3.0	—	—	—	—
POULTRY	(17)	(12.6)	(18)	(8.7)	(16)	(14.6)	(17)	(13.1)	(9)	(4.5)	(12)	(11.5)
Chicken	15	12.2	14	7.4	15	14.0	16	9.8	9	4.5	12	11.5
Turkey	1	tr.	2	0.9	1	0.6	1	3.3	—	—	—	—
Goose	1	0.4	tr.	0.4	—	—	—	—	—	—	—	—
Guinea fowl	—	—	tr.	tr.	—	—	—	—	—	—	—	—
LIVESTOCK	(15)	(9.9)	(17)	(9.3)	(7)	(3.2)	(5)	(2.5)	(22)	(22.6)	(30)	(31.7)
Pig	10	5.5	8	3.1	4	1.5	1	0.6	—	—	12	10.8
Calf	5	4.3	3	3.2	1	0.3	4	1.8	5	8.2	8	16.0
Sheep	2	0.1	5	2.4	1	1.0	—	—	16	14.4	8	3.5
Goat	—	—	1	0.6	1	0.4	1	0.1	—	—	2	1.4
MICE AND RATS	(28)	(5.5)	(39)	(9.4)	(36)	(11.8)	(27)	(11.3)	(18)	(4.6)	(16)	(1.7)
Meadow mouse	10	4.4	21	2.7	25	5.8	21	8.9	15	4.0	10	0.8
Cotton rat	1	0.1	5	3.4	4	1.5	4	1.2	—	—	—	—
Lemming mouse	8	0.6	6	0.9	3	3.8	1	1.1	2	0.2	—	—
White-footed mouse	8	0.2	9	0.9	2	0.1	1	0.1	2	0.1	2	0.2
Pine mouse	—	—	tr.	0.6	1	0.1	—	—	—	—	—	—
House mouse	3	0.2	3	0.3	3	0.2	—	—	—	—	—	—
Barn rat	—	—	1	0.5	—	—	—	—	—	—	2	0.6
Harvest mouse	1	tr.	2	0.1	2	0.3	—	—	2	0.3	—	—
Mouse, unclassified	1	tr.	tr.	tr.	2	tr.	2	tr.	—	—	2	tr.
OTHER MAMMALS	(10)	(5.8)	(12)	(7.3)	(9)	(2.5)	(18)	(10.2)	(20)	(29.3)	(8)	(7.0)
Raccoon	1	2.2	1	0.5	1	0.1	2	0.9	6	18.1	—	—
Deer	4	1.6	4	2.1	1	0.8	4	0.6	4	4.8	2	0.9
Woodchuck	1	0.7	2	1.4	1	1.0	4	1.5	6	4.3	—	—
Fox squirrel	1	tr.	2	1.0	2	0.3	4	4.9	—	—	2	tr.
Opossum	1	0.2	2	1.3	1	tr.	—	—	—	—	2	5.3
Gray squirrel	2	0.1	tr.	0.3	—	—	1	0.6	2	2.0	2	0.8
CARRION	4	1.9	5	3.5	11	8.6	12	12.7	22	14.9	6	1.9
INVERTEBRATES	4	tr.	5	0.6	8	1.4	10	2.6	9	tr.	18	1.0
BIRDS	9	0.6	7	0.6	6	0.4	5	0.3	5	1.0	2	tr.
PLANT FOODS	17	1.0	14	0.8	22	3.0	25	5.5	34	3.2	22	0.7
Total Volume (cc.)	29,235		49,914		36,210		12,130		8,177		6,388	

Only stomachs containing a measurable amount of food were included. In addition, 125 stomachs, or 14 per cent of those collected, were empty. A total of 56 animal, 28 plant, and 6 miscellaneous items, in addition to carrion, were identified. Annual and seasonal data are presented in Tables 2 and 3.

Additional coyote food-habits data were derived from the analyses of 326 scat samples collected intermittently from 1947 through 1956. Results of this study appear in Table 4. Since scat analyses are considered to be less accurate than stomach analyses for food-habits studies, these results will be discussed separately later in this report.

Principal Foods

Rabbits were the staple food of greatest importance in the coyote diet during the six years covered by the study. Cottontail, which is state-wide in distribution, provided the greatest bulk. Lesser amounts of two species of jackrabbits—the black-tailed (*L. californicus*), of southwestern and central

TABLE 3.—FOODS OF COYOTES IN MISSOURI, BY SEASON

Food Group	Season[1] / No. Stomachs	Percentages by Occurrence and Volume							
		Spring 102		Summer 51		Fall 181		Winter 436	
		Occ.	*Vol.*	*Occ.*	*Vol.*	*Occ.*	*Vol.*	*Occ.*	*Vol.*
Rabbits		57	48.6	51	35.2	52	47.7	64	58.1
Poultry		29	17.0	28	27.4	14	12.8	12	8.5
Livestock		15	16.5	14	17.5	12	7.2	14	7.6
Mice and rats		27	5.4	16	5.6	37	9.0	34	9.5
Other mammals		11	6.6	12	6.7	17	8.3	10	7.5
Carrion		11	5.0	8	4.3	6	4.3	9	6.6
Invertebrates		1	tr.	41	1.9	18	3.5	1	tr.
Birds		3	0.7	14	0.6	4	0.4	7	0.5
Undetermined animal		—	—	2	tr.	1	0.1	1	0.6
Plant foods		7	0.2	49	0.8	34	6.5	14	0.9
Miscellaneous		—	—	—	—	3	0.2	2	0.2

[1] Spring: March, April, May
Summer: June, July, August
Fall: September, October, November
Winter: December, January, February

Missouri; and the white-tailed (*L. townsendi*), in the northwestern part of the state —appeared occasionally. State-wide, rabbits accounted for more than one-half of all food eaten—55 per cent by occurrence; and 53.7 per cent of the volume of the 770 coyote stomach contents.

The percentage of rabbit in the diet varied both annually (Table 2) and seasonally (Table 3). Changes in the annual take of rabbits generally agree with population trends, as shown by Wight (1955). Census data show a steady decline in Missouri's rabbit population during the years 1949–53. Population indices, based upon rabbits per mile of census route, were as follows: 0.64, 0.62, 0.55, 0.40, and 0.38, respectively. The coyote food data show the same trend. Percentages, by volume, were as follows: 61.2, 58.7, 54.4, 41.4, and 19.2. The take of rabbits by coyotes during 1953–54 increased over the preceding year to 44.2 per cent, but census data for comparison were considered unreliable, due to abnormal weather. The concensus of field workers, however, was that rabbit populations, by region, were considerably higher than during the preceding year—an opinion supported by coyote food data, as determined from a smaller sample with poorer distribution. An upward trend in rabbit numbers was further shown by the higher census index of 0.74 rabbits per mile of census route the following year (1955).

Fig. 1 is a graphic comparison of the rabbit population index and percentage of rabbit in the coyote diet for five years, 1948–49 to 1952–53. A close relationship is indicated, as shown by the graph. Statistical analyses demonstrated this relationship,

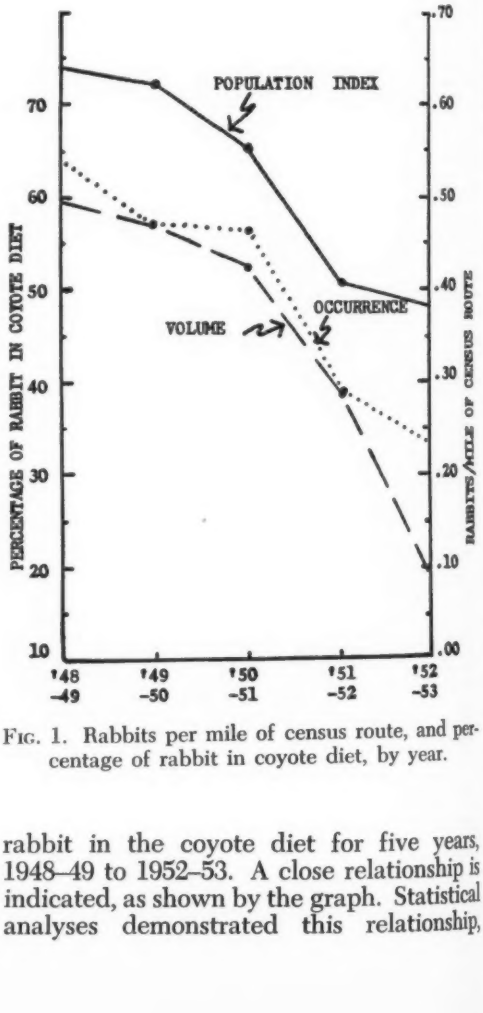

FIG. 1. Rabbits per mile of census route, and percentage of rabbit in coyote diet, by year.

TABLE 4.—FOODS OF THE COYOTE IN MISSOURI, 1948–56
(Based upon examination of 326 scat samples)

Food Item	Per Cent by Occurrence[1]	Per Cent by Volume
RABBITS	(80.4)	(64.2)
Cottontail	79.4	63.5
Jackrabbit	0.9	0.7
MICE AND RATS	(28.5)	(13.1)
Meadow mouse	19.0	7.2
Lemming mouse	6.4	3.7
Barn rat	0.9	0.7
White-footed mouse	4.9	0.5
Cotton rat	0.9	0.4
Pine mouse	1.2	0.4
House mouse	1.2	0.1
Harvest mouse	0.3	0.1
Mouse, unclassified	0.9	tr.
OTHER MAMMALS	(8.9)	(5.2)
Gray squirrel	1.8	1.5
Fox squirrel	1.8	1.4
Woodchuck	1.5	0.9
Opossum	0.6	0.5
Skunk	1.5	0.4
Raccoon	0.3	0.4
Short-tailed shrew	0.6	0.1
Muskrat (*Ondatra zibethica*)	0.3	tr.
Least shrew	0.3	tr.
POULTRY	(2.8)	(1.2)
Calf	0.9	0.6
Pig	1.5	0.4
Lamb	0.3	0.2
INVERTEBRATES	(10.4)	(0.8)
Short-horned grasshoppers	6.7	0.5
INVERTEBRATES (Continued)		
June-beetles (Scarabaeidae)	1.8	0.2
Caterpillars and coccoons	0.9	0.1
Crayfish	0.6	tr.
9 additional kinds of insects, each in "trace" amount		
BIRDS	(9.5)	(0.4)
Songbirds	3.4	0.2
Birds, unclassified	4.9	0.1
Quail	0.9	0.1
Egg shells, unclassified	0.3	tr.
FISH	0.3	0.1
SNAKE	0.3	tr.
BONE, UNCLASSIFIED	0.3	tr.
PLANT FOODS	(35.3)	(13.1)
Persimmon	16.9	9.1
Grass and sedge leaves	15.0	1.6
Apple	0.9	0.7
Mulberry	1.8	0.6
Pear	0.9	0.4
Corn	1.8	0.2
Wild plum	1.5	0.2
Plant debris	0.9	0.2
Blackberry	1.5	0.1
16 additional plant foods, each in "trace" amount		
MISCELLANEOUS	(1.8)	(0.4)
Cloth	0.9	0.2
Sash cord	0.3	0.1
Garbage	0.3	0.1
Wool matting	0.3	tr.

[1] These percentages have been carried one digit past the decimal point for comparative purposes and not to indicate that this digit is a significant one.

with a correlation coefficient of 0.92 between population index and volume of rabbit in the coyote diet, and 0.98 between population index and occurrence of rabbit.

Rabbit-harvest data obtained by Crawford (1954) show less correlation with coyote feeding trends than do the census data. Kill-per-gun-hour indices were as follows for the years 1948–49 to 1953–54: 0.79, 0.66, 0.82, 0.80, 0.52, and 0.54, respectively. Harvests, however, are subject to greater seasonal influence by weather and other factors. Heavy snows materially increase the rabbit harvest in Missouri. In mild winters with little snow, on the other hand, rabbits are less concentrated in heavy cover and a lower total harvest results. The kill (or harvest index) thus can be materially affected by a few days or weeks of ideal hunting weather.

Seasonal data (Table 3) show that the greatest take of rabbits by coyotes occurs during the winter (64 per cent occurrence and 58.1 per cent by volume), while rabbit is of least importance in the diet during the summer (51 per cent occurrence and 35.2 per cent by volume). Consumption of rabbits during spring and fall was nearly the same: 48.6 and 47.7 per cent, by volume, respectively.

The volume of rabbit in the Missouri coyote diet (53.7 per cent) was considerably greater than the 33.25 per cent in western coyotes found by Sperry (1941), approximately the same as 54.0 per cent in Nebraska coyotes recorded by Fichter, *et al.* (1955), and only slightly less than the 55.7 per cent, by weight, reported by Tiemeier (1955) for Kansas coyotes.

Poultry, as a group, provided the second most important source of food. Four species were identified in the stomach contents—

chicken, turkey, goose, and guinea fowl—but only chicken was of major importance. Poultry was identified in 16 per cent of the stomachs, and made up 11.5 per cent of the total contents. A portion of this item undoubtedly represented carrion, which could not be identified as such. Mortality in farm chickens is not unusual, and dead birds are commonly discarded in a distant field or out-of-way place. Many such carcasses can be fed upon by coyotes and other predators. The state of preservation of these birds during the winter leaves no clue to the proper identification of carrion when found in a predator stomach. The percentage of poultry listed above is considered atypical of predation and as a maximum for this reason.

Dixon (1925), after impartial study, concluded that one-half of the domestic stock, one-fourth of game, and one-eighth of rodents found in coyote stomachs represent carrion. Application of these conclusions to Missouri data would make the figures of poultry losses to coyotes appear more realistic. Tiemeier (*op. cit.*), in his study of the winter foods of Kansas coyotes, reported that it appeared unlikely that an average of 7.4 per cent of the coyote's winter diet would consist of chickens that they had caught and killed, since most chickens were penned during these months.

Little variation was noted in the occurrence of poultry in the coyote diet from year to year; it was found in an average of approximately one-sixth of the stomachs examined. Volumetric percentages showed greater annual variation, from a high of 14.6 per cent during 1950–51 to a low of 4.5 per cent in 1952–53.

Seasonal consumption of poultry conforms to the expected. Utilization of this type of food was greatest during the summer months, when coyotes took more than three times the amount taken during the winter period (Table 3). Farm flocks often are kept penned during the late fall and winter, and otherwise do not range far. Less penning, greater feeding range of the birds, greater food requirements for feeding pups, and better cover in which predators can hide and stalk their prey lead to greater take of poultry during the spring and summer months.

Livestock, as a group, ranked third in the coyote diet. Four species were identified. Calf, pig, and sheep were taken most frequently, while goat was less often found. Collectively, livestock occurred in 14 per cent of the stomachs, and made up 8.9 per cent of the total food. As with poultry, this category probably included some carrion.

The coyote generally is condemned as a killer of livestock. Most hunters and trappers agree that potentially the threat is present, but that normally the marauder type is the exception. An investigation of this kind records mainly the last meal of each animal concerned, but the results clearly show that many foods other than livestock and poultry are relied upon for subsistence.

Data in Table 2 show what may be considered to be a normal consumption of livestock during the first two years of this study when rabbits and small rodents were in good supply. Abnormally high small-rodent populations were experienced during the next two years, and the amount of livestock in the diet decreased to approximately one-third of the previous total. Both rabbit and small-rodent populations were low during the last two years of this study, as determined by field checks and observation. A smaller supply of favorite foods apparently forced greater predation upon livestock, which amounted to about three times that of the first two years, and about ten times as great as when the small-rodent population was at a peak.

The occurrence of livestock in coyote stomachs remained nearly constant for each season of the year, being found in from 12 to 15 per cent of the samples examined. Amounts found during the spring and summer months were more than twice that for fall and winter (Table 3).

Mice and rats provided the fourth most important source of food. Nearly one-third (32 per cent) of the animals had fed upon this kind of food, which made up 8.7 per cent of the total volume.

Meadow mouse accounted for more than one-half of this category of food, and occurred most consistently of the small rodents. Greatest consumption of meadow mice occurred during the year 1951–52, as 8.9 per cent of the total coyote diet, although the greatest take of all mice and rats combined was in the preceding year with a total of 11.8 per cent. The smallest take was during 1953–54, being 1.7 per cent for all

species, concurrent with a very low small-mammal population.

Cotton rats were important in the southwestern part of the state during three of the six years. No cotton rats were found in stomachs collected during the last two years of this study; and no records for this animal were established for the area north of the Missouri River. Lemming mice occurred in greatest amount concurrently with the greatest consumption of meadow mice—from 1950 to 1952—an indication that population fluctuations of these two species may occur together.

A seasonal analysis of data showed that mice and rats occurred in the coyote diet more frequently and in greater quantity during the fall and winter, with greatest volume during the winter months. This may be attributed to greater availability following the reproductive period, and to decreased ground cover which aids the coyote in locating this type of food. Mice and rats made up 9.5 per cent of the winter diet of the coyotes, an amount comparable to 9.4 per cent found by Tiemeier (1955) in Kansas.

The coyote ordinarily supplements small food items, like mice, with other foods to make a meal. Occasionally, however, these animals feed exclusively upon small rodents, as the records show. One stomach examined showed that the coyote had taken 23 meadow mice and 5 lemming mice for a single meal. Another stomach contained 7 house mice and 6 meadow mice, while still another showed 9 pine mice taken at a single feeding.

When cotton rats were abundant in southwestern Missouri (1949–50), coyotes fed heavily upon them. Analyses showed that cotton rats occurred in more than one-half (53 per cent) of the 19 stomachs, and comprised 38.2 per cent of all food in the region during that year. Percentages during the following two years for 27 and 23 stomachs, respectively, were: 33 per cent occurrence and 18.8 per cent volume; and 17 per cent occurrence and 19.4 per cent volume, respectively. The cotton rat population had largely disappeared after the third year, according to cooperators' reports, and none were found in coyote stomachs examined. During the cotton rat irruption in this area, the coyote proved to be a highly beneficial predator by consuming a large number of these rodents.

A number of other mammals, both game and nongame, contributed to the coyote diet. Occasionally a large quantity was taken at a single feeding, but occurrences were few. These have been included in a single category, simply as "other mammals." Collectively, items in this group were found in 12 per cent of the stomachs, and made up 7.5 per cent of the total food. Raccoon, deer, and woodchuck each comprised more than 1.0 per cent of the total volume, while fox squirrel, opossum, gray squirrel, gray fox, house cat, ground squirrel, skunk, short-tailed shrew, spotted skunk, least shrew, and mole were taken in lesser amounts, in that order. It is probable that much, if not most, of the deer item should have been classified as carrion. Many of the stomachs that contained deer remains were from coyotes collected during or immediately following the hunting season. Greatest utilization of "other mammals" as food occurred during the low rabbit and mouse year of 1952–53. For detailed information on specific use, see Tables 1 and 2.

Known carrion of various kinds was found frequently as part or all of a coyote's stomach contents. This type of food was recorded in 9 per cent of the samples and comprised 5.8 per cent of the total bulk. In contrast to the poultry and livestock categories, the percentages here probably are minimal. Those foods that showed evidence that the feeding animal did not make a fresh kill were listed as carrion. These included hog, cow or calf, chicken, deer, woodchuck, goat, and sheep, which obviously were not fresh materials. Other items perhaps should have been classified as carrion. Highway-killed animals on which coyotes fed, for example, should rightly be considered carrion, but usually could not be identified as such. The amount of carrion varied greatly in the annual food lists—from a low of 1.9 per cent to a high of 14.9 per cent. Seasonal fluctuations showed less variation, with greatest amounts having been taken during winter and spring, and lesser amounts during summer and fall.

Invertebrates of at least 18 different kinds, mostly insects, made up a small portion of the coyote diet. Collectively, invertebrates comprised only 0.8 per cent of the food

volume. All of these foods, except crayfish, were terrestrial forms, most of which were taken during the summer and fall months.

Birds of all kinds, except poultry, scarcely merit mention as coyote food. Eleven occurrences of quail made up only 0.2 per cent of the diet. Seven of these birds were found in stomachs of coyotes collected during the open season for quail (November 10–December 31) and may have represented crippled or lost birds. Two occurrences were from animals taken in January, and one each in August and September. The August sample contained a young quail, while the September sample contained a quail and eggs—evidence that a nest had been destroyed. The data show that a few quail are eaten by coyotes, but also clearly indicate that predation by coyotes is no menace to the quail population in Missouri. Unclassified birds, crows, and songbirds together made up another 0.3 per cent of the coyote diet. Several occurrences listed as "unclassified" consisted of feather quills which could not be further identified. Among the songbirds were items tentatively identified as meadowlark (*Sturnella magna*), cardinal (*Richmondena cardinalis*), and flicker (*Colaptes auratus*).

Extent and Effect of Coyote Predation

The extent and effect of predation upon game and domestic animals are difficult to measure, even with the aid of comprehensive food-habits data. Many factors are involved in addition to details of what the animals eat, as pointed out by Latham (1951). Availability of prey species, density of predator populations, abundance or scarcity of buffer foods, and many other factors all play vitally important roles in interpretation of predator-prey relationships. Stomach examinations themselves cannot be completely accurate, even when performed by a trained analyst. Unidentified items, as such, can be reduced to a minimum, but simple identification is not always sufficient. A case in point is the category "carrion" found listed in nearly all food-habits reports on predators. Carrion invariably represents, in part, an unknown which must be dealt with for proper interpretation of data, yet accurate appraisal or measurement of this category of food cannot be made. Putrefied or maggot-infested flesh will be listed as carrion, without question. Yet this material might just as logically have resulted from parts cached by a predator from a previous kill. Highway-killed animals, unretrieved hunters' kills, discarded poultry, and livestock losses all serve to complicate interpretation of data. Thus, it becomes virtually impossible for a single investigator to amass sufficient data during the course of a study to adjudge the results properly when he is through.

One method of analysis is to consider that coyote predation counters man's interest when a coyote takes a creature that man wanted for himself. The assumption follows that man wants game, poultry, and livestock, the loss of which would be considered "harmful." Because rodents, carrion, and insects are not wanted, feeding upon them might be considered as beneficial, while such items as nongame mammals and birds, plant foods, and miscellaneous items might be classed either as beneficial or neutral.

The totals of this "unwanted" predation for the 770 coyotes collected from throughout the state during six years were as follows: game species aggregated 59.3 per cent of the food volume; poultry added another 11.3 per cent; livestock increased these amounts by another 8.9 per cent—for a grand total of 79.5 per cent. Basically then, it would appear that evidence against and for the coyote is in ratio of about 4 to 1. If we wish to concede that some of the game and a somewhat larger portion of poultry and livestock consumption did not represent coyote kills, the extent of damage would be lessened proportionately, but evidence against the coyote would remain at a high level.

The effect of predation is even more difficult to appraise. While rabbit makes up more than one-half of the coyote fare throughout the year, coyote numbers normally are not great in any locality. This study was conducted during the years of greatest recorded coyote abundance in Missouri, and at a time of low rabbit populations, but there was no evidence that coyotes alone had any seriously limiting effect upon man's rabbit harvest. Added to the take of rabbits by other predators, however, coyote predation may have helped cause some limiting effect in local areas of naturally low rabbit numbers. The limiting effect,

if it did occur, was not of lasting importance. This premise is strengthened by the fact that three years after the periodic low in rabbit numbers rabbits again were in good supply in 1956.

The take of other game species—furbearers, deer, squirrels, and quail—was in such small amounts as to have no material effect upon existing populations.

The kill of poultry and livestock by coyotes can be classed only as detrimental. These two classes of foods accounted for about one-fifth (20.2 per cent) of the coyote diet. A part of this may have been carrion which could not be recognized as such. A livestock or poultry kill represents a loss to agricultural interests in each case. Little credit can be given for having a coyote clean up the carcass of an animal lost from other causes, and none should be, since such animals should not be made available to coyotes. It is poor farming practice, by encouraging both predation and spread of disease, to deposit dead animals on the "back forty" as a means of disposal.

Greatest seasonal losses of livestock and poultry occurred during summer, when these two classes of foods totaled 44.9 per cent of the coyote diet. This total amounted to one-third (33.5 per cent) during spring, one-fifth (20.0 per cent) in fall, and one-sixth (16.1 per cent) during the winter months.

The six years' collection of data shows that, on the average, one coyote in three fed upon livestock and/or poultry. Corrected data, if it were possible to eliminate occurrences that did not represent actual coyote kills, probably would make this average nearly one in every four or five coyotes.

Results of Scat Analyses

A list of foods, with percentages by occurrence and volume, obtained from the analyses of 326 coyote scats comprises Table 4. The scats collected from two widely separated areas of the state represent all seasons. Approximately one-half of the total number were collected from the August A. Busch Memorial Wildlife Area, St. Charles County, under the direction of Willard Barbee, Area Biologist, during the period from December 1947 to June 1949. The remainder were collected from a 35-square-mile area in Cass County by Henry B. Stuart during the period from October 1952 to October 1956. Collections, therefore, were made in the east-central and west-central parts of the state.

Principal foods shown by stomach and scat analyses were essentially the same, but percentages differed. Rabbits were shown to be the most important food in both studies, but showed up more often and in greater amounts in the scats. This may be attributed to the higher rabbit populations of central Missouri and lack of representation by scats from southern Missouri where fewer rabbits are found.

Mice and rats also were found in greater proportions in the scats and amounted to 13 per cent of the total volume, as compared to 9 per cent in stomachs. Occurences were fewer in the scats, however; 28 per cent and 32 per cent, respectively. Mice and rats of at least eight species were identified in the scat contents, the same as found in the stomachs. The high mouse populations found on the A. A. Busch Area during early collections possibly accounted for this difference in consumption of mice and rats. The fallow fields were ideal feeding range for coyotes.

Other mammals, as a group, ranked as the third food category by scat analyses, and fifth by stomach analyses. Squirrels and woodchuck served to raise the average take of this type of foods. Nine different animals were included in this group, as shown in Table 4.

The smaller amount of poultry and livestock found in scats is largely due to a lack of availability. Neither of these foods was available on the A. A. Busch Area, although small amounts were taken from surrounding farms and from the Cass County area in the west-central part of the state.

Invertebrates were found in slightly greater amounts in scats, while other animal foods were in approximately the same amounts, taken infrequently and in small portions.

Plant foods made up a much greater percentage of the scats and amounted to 13 per cent of the total volume. This high percentage was due largely to the influence of persimmon fruits which were readily available in quantity. Grass, apple, mulberry, pear, corn, and wild plum were the other principal plant foods.

CONCLUSIONS

This investigation showed that, in terms of man's interests, coyote feeding is largely detrimental. Game, poultry, and livestock made up a major portion of the coyote diet. Direct predation upon prolific game species, especially the rabbit, may be beneficial to the species by eliminating the weak, diseased, and unfit. For this reason, predation upon game is not totally bad. The total direct kill of poultry and livestock more nearly represents detrimental feeding, but the practice of discarding dead farm animals where they may be fed upon by coyotes makes evaluation of the actual kill difficult.

Predator-control personnel long have recognized that only individual coyotes develop destructive feeding habits and must be eliminated. The Missouri Conservation Commission's present predator-control policies are based upon this fact. Some of the stomachs examined in this study were obtained from animals taken in predator-control operations and this, plus the fact that only the animal's last meals are involved, may well mean that the data in this report somewhat exaggerate indications of destructive feeding. The long list of food clearly shows, however, that much foods besides poultry, livestock, and game is consumed by the coyote.

SUMMARY

In Missouri, 770 coyote stomachs, collected by individual hunters and trappers, county clerks, conservation agents, refuge personnel, biologists, and field-service agents of the Conservation Commission, contained a total of 56 animal, 28 plant, and 6 miscellaneous items. Principal foods of coyotes, by volume, were: rabbits, 53.7; poultry, 11.3; livestock, 8.9; mice and rats, 8.7; other mammals, 7.5; carrion, 5.8; invertebrates, 0.8; birds, 0.5; undetermined animal matter, 0.4; plant foods, 2.0; and miscellaneous, 0.2 per cent, respectively.

A close relationship existed between the rabbit population, as determined by roadside census, and the percentage of rabbit in the coyote diet. Statistical analyses demonstrated this relationship, with a correlation coefficient of 0.92 between population index and volume of rabbit, and 0.98 between population index and occurrence of rabbit in the coyote diet.

The data suggest that coyote predation, added to the take of rabbits by other predators, may have had some temporarily limiting effect upon populations in areas of low rabbit densities. Such effect, if present, was of short duration.

Some of the stomachs examined in this study were obtained from animals taken in predator-control operations, which may have exaggerated indications of destructive feeding.

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MANDIBULAR DENTITION AS AN AGE INDICATOR IN ROCKY MOUNTAIN ELK[1]

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The value of age-class composition in big-game management is well known and has been adequately discussed by various authors. Published reports on dentition as related to age in the elk (*Cervus canadensis*) include those of Banfield (1949), Murie (1951), Swanson (1951), Quimby and Gaab (1952), and Hancock and Low (1956). Although much information is included in these publications, it would appear that the additional information secured by the present authors since our preliminary report is worth recording. One hundred and sixty-eight known-age and 527 assigned-age specimens (*see* Terminology) from Montana and Yellowstone National Park became available from 1949 to early 1955 for dentition studies (Table 1). The entire skull of most known-age specimens was retained but, following the procedure of Severinghaus (1949) for white-tailed deer (*Odocoileus virginianus*), only the mandibular dentition is considered in the present evaluation.

As specimens were added to the collection, it became apparent that—in the life cycle of elk—deciduous teeth were lost and replaced by permanent teeth in an orderly manner. Teeth with no predecessors (molars) were erupted in a definite sequence. Although some variation in replacement and eruption did exist, animals less than three years old were readily segregated into year classes on the basis of types (deciduous or permanent), number, and stage of eruption of teeth. For animals with complete permanent dentition, the amount of wear on the incisors and cheek teeth (premolars and molars) appeared, in general, to be roughly correlated with age. When only a few specimens were available early in the study, it appeared that the various age classes with permanent dentition could be segregated on the basis of wear patterns on the occlusal surface of the teeth. As more specimens became available, it appeared obvious that individual differences within year classes did exist and that large numbers of specimens would be necessary for critical evaluation. Some of the more obvious differences were as follows: (1) Some animals show considerably more wear on the incisors as compared with wear on the cheek teeth than do others, and vice versa; (2) the teeth in

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opposite jaws of the same animal do not always wear the same, and in some instances the difference is quite striking; (3) certain teeth in some animals wear exceptionally fast, e.g., a molar in a 2-year-old being worn to the extent of resembling that of an elk 10 years old or older; (4) the teeth of some animals show different wear patterns than the teeth of others of the same year class; thus in some older specimens, the wear on the premolars is heavy as compared with that on the molars, while the reverse is true in others; (5) there are differences in the structure of certain teeth of some animals as compared to the same teeth of others. These individual differences obviously indicated that the use of single characters for segregating year classes would lead to erroneous conclusions.

In attempting to describe differences in the teeth of various year classes, it became apparent that descriptive terminology (worn more, more dentine exposed, etc.) would be of little value in the absence of specimens for comparison. To be of greatest value, distinguishing characters should be such that they are either present or absent (positive or negative). It was noted that definite patterns of enamel and/or dentine were formed temporarily on the occlusal surface of the cheek teeth as wear progressed. Further wear obliterated these patterns while producing others. Some were amenable to positive or negative classification. Wear on the incisors, although definite and positive, did not result in the formation of patterns readily describable. Only the mandibular cheek teeth are therefore considered here. Crown heights were indicative of wear, but practical implications discouraged the use of this feature. The examination of hunter kills does not lend itself to making such measurements. Furthermore, it has been observed that the gum line recedes in at least some old animals.

Although a relatively large number of known-age (from ½ to 21 years old) and assigned-age specimens are available (Table 1), it appears the material is inadequate for evaluation of the older year classes. However, drawings of the mandibular cheek teeth of 7-, 8-, 9-, 15-, and 21-year-old elk are included.

The writers gratefully acknowledge the help of the following: Walter Kittams, Yellowstone National Park, for supplying several known-age specimens and the majority of the assigned-age specimens used in the study; P. L. Wright, Montana State University, for contributing two known-age specimens and for several suggestions; E. L. Cheatum, formerly leader of the Montana Cooperative Wildlife Research Unit, for cooperation in collecting known-age specimens; former graduate students of Montana State College for help in preparation of specimens and evaluation of aging by use of the jaw board; many others too numerous to mention who contributed in one way or another during the course of the study. The drawings were made by E. Herbold Froeschner.

TERMINOLOGY

Known-age specimen.—A specimen which was aged from tagging records (Montana Fish and Game Department, U.S. Park Service, U.S. Forest Service). In most instances the animal was tagged when only a few days old. Most elk calves are born during late May or early June in this locality (Johnson, 1951; Brazda, 1953). When newborn and for a few days thereafter, they can be caught and tagged. In five instances, animals were trapped and tagged during their first winter at ages ranging from about 6 to 8 months (elk of this age are readily recognized at close range by experienced workers). One male was trapped and tagged during its second winter (the spike antler of the yearling male is diagnostic). Date of death was verified in almost all instances by the individual who made the kill. For a few hunter kills, only the hunting season when the kill was made was known. In a few instances where death was due to causes other than hunting, only an estimate of date of death was available. Exact date of death was of no particular importance to this evaluation because only year classes are considered. Three known-age specimens were not used. One 5-year-old and one 23-year-old had been semidomesticated. An "11-year-old," was not used because only one dentary, less the incisors, was available, and the wear on the teeth present was so far "out of line" with other known-age specimens that the writers suspected a mix-up in the records.

Assigned-age specimen.—A specimen

TABLE 1.—AGE CLASS, DRAINAGE LOCATION, AND MONTH OF KILL FOR 168 KNOWN-AGE AND 527 ASSIGNED-AGE ELK

Age Class[2]		Number of Specimens by Drainage Location and Month[1]																			
		Yellowstone							Gallatin							Madison			Beaverhead		
		S	D	J	F	M	A	FW	O	N	D	J	F	M	A	FW	O	N	FW	N	Total
Calf	K	–	–	16	1	–	–	–	1	9	6	12	3	1	5	–	–	–	–	–	54
	A	–	–	20	16	1	–	1	–	–	–	–	–	1	–	–	–	–	–	–	39
One	K	–	2	21	–	–	–	–	5	12	6	7	–	–	–	–	–	–	–	–	53
	A	–	1	39	17	–	1	6	–	3	–	–	–	–	–	1	–	–	–	–	68
Two	K	1	–	2	1	–	–	–	3	6	4	4	–	–	–	–	–	–	1	–	22
	A	–	1	20	9	–	–	9	–	1	–	–	–	–	–	–	–	–	–	–	40
Three	K	–	1	4	1	–	–	–	2	6	–	1	–	–	–	–	–	–	–	–	15
	A	–	–	9	5	–	–	2	–	–	1	–	–	–	–	–	–	–	–	–	17
Four	K	–	–	6	–	–	–	–	–	–	–	1	–	–	–	–	–	1	1	–	9
	A	–	–	21	14	–	–	4	–	–	–	–	–	–	–	–	–	–	–	–	39
Five	K	–	–	1	–	–	–	–	–	2	2	3	–	–	–	–	–	–	–	–	8
	A	–	–	20	3	–	–	–	–	–	–	–	–	–	–	1	1	–	–	–	25
Six	K	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	A	–	1	27	7	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	40
Seven	K	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
	A	–	1	42	8	–	–	4	–	1	–	–	–	–	–	1	–	–	–	–	57
Eight	K	–	–	–	–	–	–	–	–	2	–	1	–	–	–	–	–	–	–	–	3
	A	–	1	37	20	1	–	3	–	1	–	–	–	–	–	2	–	–	–	–	65
Nine	K	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	1
	A	–	1	25	20	–	–	2	–	1	–	1	–	–	–	1	–	–	–	–	51
Fifteen	K	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1
	A[3]	–	–	31	15	–	–	6	–	–	–	1	–	–	–	1	–	–	–	–	54
Twenty-one	K	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
	A[4]	–	–	15	7	–	–	3	–	1	–	–	–	–	–	6	–	–	–	–	32

[1] S=Sept., O=Oct., N=Nov., D=Dec., J=Jan., F=Feb., M=March, A=April, FW=Fall or Winter

[2] K=Known-age, A=Assigned-age.

[3] Under 15—over 9.

[4] 15 or over—under 21.

which was "aged" by comparison with known-age specimens. Each mandibular cheek tooth of the unknown-age specimen was compared with its counterpart in known-age specimens of various age classes. It was assigned to the year class that it most closely resembled in tooth characteristics (types of teeth, number of teeth, wear on permanent teeth). The authors recognize that some assigned-age specimens may have been erroneously aged. Known-age and assigned-age specimens are evaluated separately and in combination in the tables that follow. We are of the opinion that the increased sample size justifies the use of assigned-age specimens. Even if some were erroneously aged, they are still of value in evaluating characters for a specimen showing a certain degree of tooth wear.

Year class.—The time interval into which specimens are segregated. Specimens used in the study became available from September to April (Table 1). Thus, all year classes are some 3 to 10 months older than the designated year class signifies. On the average, yearlings are more nearly 1½ years old; two-year-olds are more nearly 2½ years old; etc. Animals killed during their first fall (winter) are calves; second fall, yearlings; third fall, 2-year-olds; fourth fall, 3-year-olds; etc.

Teeth.—The complete mandibular deciduous (milk) dentition of the elk consists of deciduous incisor one DI_1, deciduous in-

cisor two DI_2, deciduous incisor three DI_3, deciduous incisor four DI_4 (an incisiform canine), deciduous molar two DM_2, deciduous molar three DM_3, deciduous molar four $DM_4 \times 2 = 14$ teeth (Fig. 1). The complete mandibular permanent dentition consists of incisor one I_1, incisor two I_2, incisor three I_3, incisor four I_4, premolar two PM_2, premolar three PM_3, premolar four PM_4, molar one M_1, molar two M_2, molar three $M_3 \times 2 = 20$ teeth (Fig. 1). Size will distinguish deciduous and permanent incisors (Fig. 1). Two simple methods will distinguish whether deciduous molars or premolars are present. Lower DM_4 has three cones (*see* below); lower PM_4, two cones. More wear is apparent on the occlusal surface of deciduous molars than on the molars (one, two, or three may be present in specimens with deciduous molars). The reverse is true in specimens with newly erupted premolars.

The following terms are used in tooth descriptions: *cones,* the divisions of a cheek tooth (Fig. 1); *crown,* the part of a tooth above the gum; *occlusal surface,* the grinding surface of a tooth; *infundibulum,* the concavity in the occlusal surface of a cone of a cheek tooth; *lingual crest,* the crescent-shaped ridge bordering the infundibulum on the side toward the tongue (in a newly erupted tooth this ridge is covered with enamel; but as the tooth wears, the dentine is exposed between the layers of enamel); *buccal crest,* the crescent-shaped ridge bordering the infundibulum on the side toward the cheek; *enamel,* calcified epithelial tissue covering the crowns of teeth; *dentine,*. calcified epithelial tissue which forms the main portion of teeth (underlies the enamel and is distinguished from it by it brown color as opposed to white).

YEAR-CLASS CRITERIA

Calf

The calf is readily recognized by the dental formula $DI_{1,2,3,4}$ $DM_{2,3,4}$ $M_1 \times 2$ (*see* Fig. 1). Fifty-two known-age and 38 assigned-age specimens collected from October to April (Table 2) revealed no deviation from this formula, but the posterior lingual and buccal crests of M_1 were not erupted in all specimens. The posterior buccal crests of 9 of 10 October–November specimens and the posterior lingual crests for 3 of these 9 had not erupted. The posterior lingual and posterior buccal crests of 1 of 80 December–April specimens had not erupted.

Yearling

Yearlings show an advancement in dentition (Table 3) as compared with calves (Table 2). Molar two had erupted on both sides in all of 114 specimens. Only 1 of the 114 retained all deciduous incisors. For all others, permanent incisors had replaced from 1 to 4 of deciduous incisors one and two. DI_1 was replaced first, then DI_2. All specimens retained deciduous incisors three and four on both sides. On the average, the number of permanent incisors present is correlated with age. Thus, none of 20 October–November specimens showed I_2 in place of DI_2 on both sides. One had I_2 on one side but DI_2 on the other. All but two had I_1 on both sides. One of these had DI_1 on one side, I_1 on the other. The other retained DI_1 on both sides. Three of nine December specimens had I_2 on both sides. One had DI_2 on one side and I_2 on the other. DI_1 was not represented in December specimens. Twenty-nine (43 per cent) of 67 January specimens had I_2 on both sides. Seven had DI_2 on one side and I_2 on the other. Thirteen (72 per cent) of 18 February–April specimens had I_2 on both sides. Three retained DI_2 on one side only, and only two retained DI_2 on both sides.

The deciduous molars of the calf remain intact in the yearling but show much more wear on the occlusal surface.

From the above, it is apparent that no dental formula consistently describes the

FIG. 1 (right). Drawings (natural size) of the left mandibular teeth of the elk. **A**—Front view of the deciduous incisors. **B**—Back view of the deciduous incisors. **C**—Front view of the permanent incisors. **D**—Back view of the permanent incisors. **E**—Side view of the deciduous molars (M_1 of permanent dentition included). **F**—Occlusal view of the deciduous molars. **G**—Side view of premolars and molars. **H**—Occlusal view of premolars and molars. A, B, E, F from a one-half-year-old elk. C, D, G, H from a three-and-one-half-year-old elk.

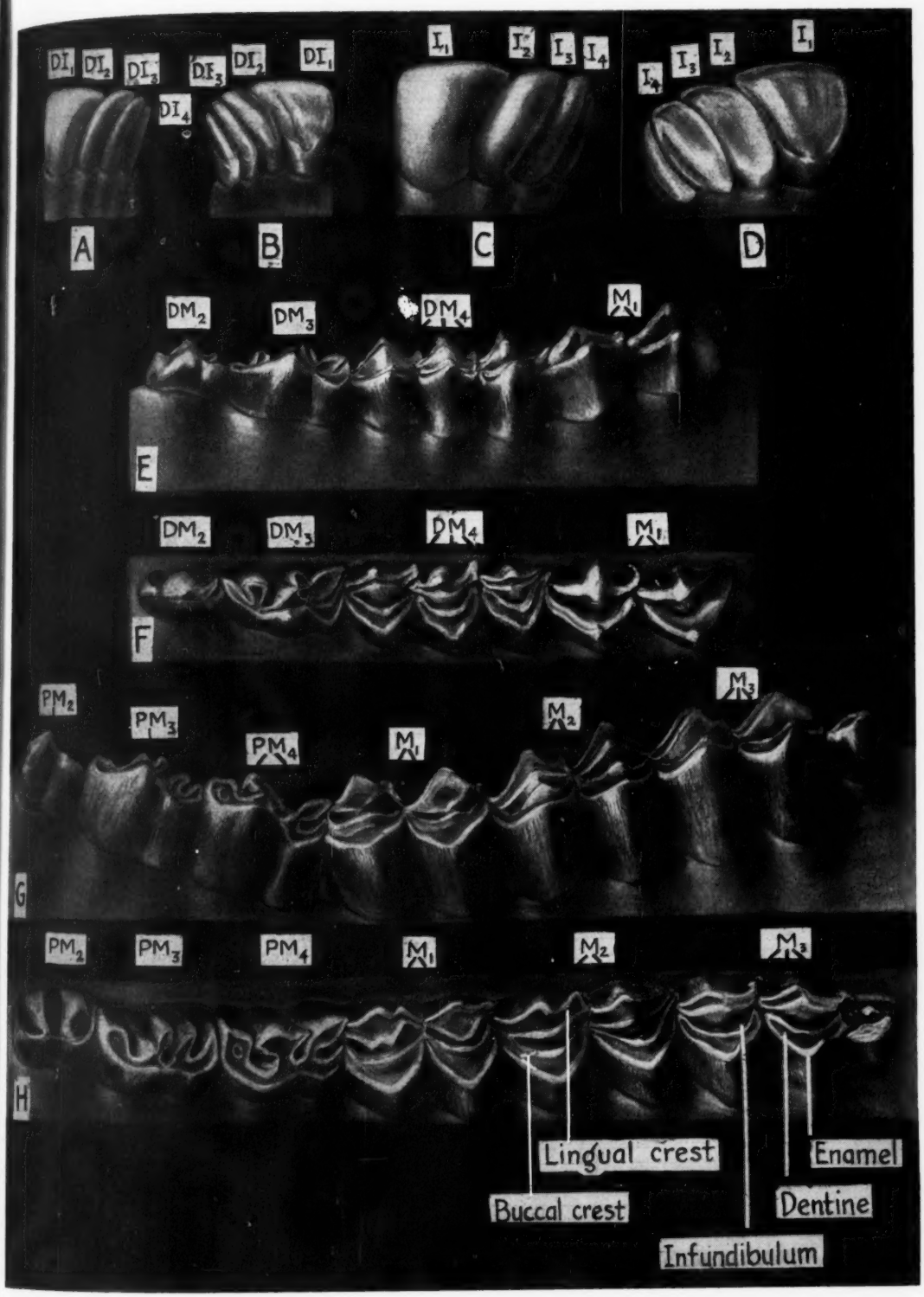

DI1 DI2 DI3 DI4 DI3 DI2 DI1
I1 I2 I3 I4
I4 I3 I2 I1
A
B
C
D
DM2 DM3 DM4 M1
E
DM2 DM3 DM4 M1
F
PM2 PM3 PM4 M1 M2 M3
G
PM2 PM3 PM4 M1 M2 M3
Lingual crest
Enamel
Buccal crest
Dentine
Infundibulum
H

TABLE 2.—MANDIBULAR DENTITION OF 52 KNOWN-AGE AND 38 ASSIGNED-AGE ELK CALVES

Month	Size of Sample			Teeth Present			Condition of M_1[4]			
	Age[1]	Sex	No.[2]	$DI_{1234}\times2$	$DM_{234}\times2$	$M_1\times2$[3]	ALC	ABC	PLC	PBC
October	K	♀	1	1	1	1	2	2	2?	0
November	K	♂	6	6	6	6	12	12	6	2
		♀	3	3	3	3	6	6	6	0
December	K	♂	4	4	4	4	8	8	8	8
		♀	2	2	2	2	4	4	4	4
January	K	♂	16	16	16	16	32	32	32	32
		♀	9	9	9	9	18	18	18	18
		?	2	2	2	2	4	4	4	4
	A	♂	6	6	6	6	12	12	12	12
		♀	13	13	13	13	26	26	24	24
		?	1	1	1	1	2	2	2	2
February	K	♂	3	3	3	3	6	6	6	6
		♀	1	1	1	1	2	2	2	2
	A	♂	2	2	2	2	4	4	4	4
		♀	1	1	1	1	2	2	2	2
		?	13	13	13	13	26	26	26	26
March	K	♂	1	1	1	1	2	2	2	2
	A	♀	1	1	1	1	2	2	2	2
		?	1	1	1	1	2	2	2	2
April	K	♂	2	2	2	2	4	4	4	4
		♀	2	2	2	2	4	4	4	4

[1] K=Known-age; A=Assigned-age.

[2] In eight (six known-age, two assigned-age) specimens a missing (broken) tooth on one side was considered to be same as one present. In two known-age specimens a tooth was missing on both sides; these specimens were not used. One assigned-age specimen was not used because of incomplete data.

[3] All crests may or may not be erupted through gum.

[4] Indicates number of crests of both right and left M_1 erupted through gum (ALC=anterior lingual crest, ABC=anterior buccal crest, PLC=posterior lingual crest, PBC=posterior buccal crest).

dentition of yearlings, but variations involve only the first two teeth. I_1 $DI_{2,3,4}$ $DM_{2,3,4}$ $M_{1,2}\times2$ and $I_{1,2}$ $DI_{3,4}$ $DM_{2,3,4}$ $M_{1,2}\times2$ were encountered most often, with the former predominating in October–January specimens and the latter in February and April specimens. Specimens with one permanent and one deciduous tooth making up a pair of the second incisors were not unusual. The same condition for the first incisor was encountered once, although specimens from early fall would probably show this condition to be common at that time.

Despite its variations, the yearling dental formula can be used to separate this age class from calves. In all instances except one, the incisors alone were sufficient. Only one yearling had all deciduous incisors (condition of calves). The presence of M_2 is conclusive; it was present in all yearlings and absent in all calves.

Two-year-old

Two-year-olds show an advancement in dentition (Table 4) as compared with yearlings (Table 3). In all but 3 of 62 specimens, permanent incisors had replaced all deciduous incisors. Two of the three had seven permanent incisors, the other six. All three were November specimens.

In all but three, premolars had replaced 1, 2, 4, 5, or 6 of the deciduous molars. It would appear that any combination of deciduous molars and premolars could be expected, but only the combinations indicated in the second footnote to Table 4 were actually observed. During an animal's

TABLE 3.—MANDIBULAR DENTITION OF 53 KNOWN-AGE AND 61 ASSIGNED-AGE YEARLING ELK

Month	Size of Sample			Teeth Present						
	Age[1]	Sex	No.[2]	$DI_{1234}\times 2$	$\frac{DI_{1234}}{I_1DI_{234}}$	$I_1DI_{234}\times 2$	$\frac{I_1DI_{234}}{I_{12}DI_{34}}$[3]	$I_{12}DI_{34}\times 2$[3]	$DM_{234}\times 2$	$M_{12}\times 2$[4]
October	K	♂	1	–	–	1	–	–	1	1
	K	♀	3	1	–	2	–	–	3	3
	K	?	1	–	–	1	–	–	1	1
November	K	♂	5	–	–	4	1	–	5	5
	K	♀	7	–	1	6	–	–	7	7
	A	♂	3	–	–	3	–	–	3	3
December	K	♂	7	–	–	4	1	2	7	7
	K	♀	1	–	–	1	–	–	1	1
	A	♂	1	–	–	–	–	1	1	1
January	K	♂	11	–	–	3	1	7	11	11
	K	♀	13	–	–	8	2	3	13	13
	K	?	4	–	–	3	–	1	4	4
	A	♂	17	–	–	7	1	9	17	17
	A	♀	21	–	–	10	3	8	21	21
	A	?	1	–	–	–	–	1	1	1
February	A	♂	8	–	–	1	2	5	8	8
	A	♀	5	–	–	1	1	3	5	5
	A	?	4	–	–	–	–	4	4	4
April	A	?	1	–	–	–	–	1	1	1
Total			114	1	1	55	12	45	114	114

[1] K=Known-age; A=Assigned-age.

[2] In 19 (6 known-age, 13 assigned-age) specimens a tooth on one side was missing (broken out); in three assigned-age specimens a tooth on both sides was missing (broken out)—size of stub and/or diastema indicated type of tooth (deciduous or permanent); seven assigned-age specimens not used because of incomplete data.

[3] I_2 varied in stage of eruption from barely through gum to full height. In one instance I_2 was coming in in front of DI_2 (DI_2 still intact). Normally I_2 comes in "under" DI_2 and "pushes it out."

[4] M_2 well advanced in eruption but seldom, if ever, completely erupted. In all specimens except one, all 4 crests were through the gum. For this one it appeared that one posterior buccal crest was not through (other 3 crests definitely erupted).

third fall and/or winter the premolars replace the deciduous molars. The deciduous molars, when present during this period, are much worn and frequently appear as "caps" over the premolars beneath them. Their roots appear to "dissolve" away. It would appear that they "break out" when the roots "dissolve" to a certain point and sufficient pressure is exerted. One elk of this age class shot in November was observed to have some of the deciduous molars loose in its mouth. Apparently the roots of these teeth were almost "dissolved" when the elk was shot and the resulting jar(s) created when the elk fell or thrashed around was sufficient to break them out. Apparently there is no particular sequence of replacement for deciduous molars (*see* second footnote to Table 4), and it is possible that in some instances they are replaced almost simultaneously. The number of specimens with all premolars is correlated with age. None of 4 September–October specimens and 7 (58 per cent) of 12 November–December specimens had all premolars. For January–February specimens the figures are 32 (89 per cent) of 36.

M_3 had partially erupted on both sides in all 62 specimens. All but five showed the first two cones erupted (*see* third footnote to Table 4). None showed the third cone completely erupted (31 not erupted at all and 31 partially erupted). The third cone

TABLE 4.—MANDIBULAR DENTITION OF 22 KNOWN-AGE AND 40 ASSIGNED-AGE TWO-YEAR-OLD ELK

Specimens Studied[1]	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Fall or Winter
K ♂	–	2	3	1	2	–	–
♀	1	1	3	1	2	1	–
?	–	–	–	2	2	–	1
A ♂	–	–	1	1	4	3	2
♀	–	–	–	–	16	5	–
?	–	–	–	–	–	1	7
Dentition Present							
$I_{1234} \times 2$	1K♀	2K♂♂,1K♀	2K♂♂,1K♀	1K♂,1K♀	2K♂♂,2K♀♀,2K??	1K♀,3A♂♂	1K?,2A♂♂
I_{1234}—$I_{12}DI_3I_4$	–	–	1A♂	2K??,1A♂	4A♂♂,16A♀♀	5A♀♀,1A?	7A??
I_{1234}—$I_{123}DI_4$	–	–	1K♀	–	–	–	–
$I_{123}DI_4 \times 2$	–	–	1K♀	–	–	–	–
$DM_{234} \times 2$	1K♀	–	1K♂	–	–	–	–
DM_s & PM_s[2]	–	2K♂♂,1K♀	2K♀♀	–	–	–	–
$PM_{234} \times 2$	–	–	–	1K♂,1K♀,1A♂	1A♂,2A♀♀	1A?	–
$M_{123} \times 2$[3]	All	All	3K♂♂,1K♀ 1A♂ All	2K?? All	2K♂♂,2K♀♀,2K?? 3A♂♂,14A♀♀ All	1K♀,3A♂♂ 5A♀♀ All	1K?,2A♂♂ 7A?? All
I_4 Stage of Eruption[4]							
Complete	–	–	–	1K♀	2K♀♀,1K??,2A♂♂	–	–
Incomplete	1K♀	2K♂♂,1K♀	3K♂♂,3K♀♀	1K♂,2K??		1K♀,2A♂♂	1K?,2A♂♂
Indeterminable	–	–	1A♂ –	1A♂ –	2K♂♂,3A♂♂,12A♀♀ 1K?,1A♂,2A♀♀	5A♀♀,1A? 1A♂	2A?? 5A??
Color of PM_s as Compared to M_s							
Lighter[5]			All specimens except the one indicated below				
Same	–	–	–	–	–	1K♀	–
M^3 Stage of Eruption of Posterior Cone							
Not Erupted	1K♀	2K♂♂	2K♂♂,3K♀♀,1A♂	1K♂,1K♀,1A♂	1A♂,10A♀♀	1A♂,3A♀♀,1A?	3A?
Partially[6]	–	1K♀	1K♂	2K??	2K♂♂,2K♀♀,2K??	1K♀,2A♂♂	1K?,2A♂♂
Complete	None	None	None	None	3A♂♂,6A♀♀ None	2A♀♀ None	4A?? None

[1] K = Known-age; A = Assigned-age.

[2] The deciduous molars are replaced by premolars during the animal's third fall or winter. No definite sequence of replacement was indicated. The following combinations of deciduous molars and premolars were represented: $\frac{PM_{23}}{PM_{234}}DM_4$(4), $\frac{PM_{234}}{PM_2DM_3PM_4}$(1), $\frac{PM_{234}}{DM_2PM_{34}}$(1), $PM_2DM_{34} \times 2$(1), $PM_{23}\ DM_4 \times 2$(1), $\frac{DM_{234}}{DM_2PM_3DM_4}$(1), and $\frac{DM_{234}}{PM_2DM_{34}}$(1). A deciduous molar was considered present if a portion remained over the permanent tooth (some were broken).

[3] M_3 not completely erupted. For most specimens the first two cones were erupted (five exceptions were recorded: for two only the first cone and lingual crest of the second cone on both sides were erupted; 1, only the first cone on both sides erupted; 1, only the first cone on one side and the first and second cones on the other erupted; and 1, only the first cone on one side and the anterior cone and lingual crest of the second cone on the other side erupted). One specimen had M_3 missing on one side (recorded according to one present).

[4] The majority were erupted 80 per cent or more. In some instances it was difficult to judge if fully erupted. A few were just through gum to about 50 per cent erupted. Some specimens had chipped I_3 and/or I_4, making it impossible to judge. Two specimens each had one I_4 missing (stage of eruption judged by I_4 present).

[5] These teeth varied from almost white when first exposed to various shades of color intermediate between white and the color of the darkly stained molars (brown to black). In some late specimens they were stained almost as much as the molars.

[6] For most specimens barely erupted (buccal crest on one side or both sides barely through gum).

was partially erupted more frequently in older specimens, e.g.: September–December, 4 of 16 specimens; January–February, 20 of 36 specimens.

Although the dental formula of 2-year-olds is variable as concerns chiefly the deciduous molars and/or premolars and also the incisors, it can be used to separate 2-year-olds from yearlings. The presence of 6 to 8 permanent incisors is conclusive (maximum for yearlings was 4). The presence of molar three is also conclusive (all yearlings had only $M_{1,2}$). The presence of at least one premolar separated all but 3 of the 62 specimens (yearlings had all deciduous molars).

Murie (1951), Swanson (1951), and Hancock and Low (1956) indicated similar tooth conditions for calves, yearlings, and 2-year-olds.

Older Than Two

Elk older than two have complete permanent mandibular dentition. Thus the dental formula will separate these animals from 2-year-olds that retain any portion of the milk dentition but it will not separate them from 2-year-olds that have lost all milk dentition. The condition of certain teeth of 2-year-olds can be used to differentiate most specimens. The stage of eruption of I_4 is of some value, since it appeared to be completely erupted in only 6 of 52 specimens evaluated (this character is not recommended, however, because of the difficulty of judging if the tooth is completely erupted in all cases (*see* fourth footnote to Table 4). The premolars are more indicative. Recently erupted premolars (previously protected by the deciduous molars) are almost white in color and contrast with the heavily stained molars (brown to black). As time passes they too stain, but in all specimens except one that was collected late in winter (February) they were lighter in color than the accompanying molars (*see* fifth footnote to Table 4). The stage of eruption of the third cone of M_3 is also an index (*see* previous discussion and footnotes to Table 4).

Although none were encountered in this study, it seems entirely possible that a 2-year-old from late winter might be sufficiently advanced in dentition development to nullify the use of the above characters either singly or in combination.

Hancock and Low (1956) give characters for distinguishing 3½-year-old elk from 2½-year-old elk as follows: (1) more darkly and evenly stained premolars, (2) definite wear of the premolars and the lateral dorsal ridges of the middle two pairs of incisors, and (3) the tip of the posterior cusp of the third or last molar stained and generally showing definite wear. The latter character is described as the most diagnostic feature of a 3-year-old, but exceptions are noted.

"Three-year-old Characters"

Five specific characters, as listed below and illustrated in Fig. 2, were prominently represented in the 3-year-old specimens.

Character I: Condition of PM_2—occlusal surface sharp; no or little wear (enamel not worn, enamel worn but no dentine exposed, or some dentine exposed but not continuous across the occlusal surface of either the right or left tooth).

Character II: Condition of PM_3—exposed dentine not continuous (interrupted by enamel) across the occlusal surface of the buccal crest of either the right or left tooth.

Character III: Condition of PM_4—an oval (circle) of enamel, which may or may not be closed, on the anterior occlusal surface of both the right and left teeth. The circle may vary in size between different specimens, but size is not important (any size circle = positive). The circle may be anything from a half circle open on one side to a completely closed circle (anything less than half circle = negative).

Character IV: Condition of M_3—posterior end (edge) of anterior lingual crest (appears as a small protuberance between the anterior and medial lingual crests) completely covered with enamel (no dentine exposed) on both the right and left teeth.

Character V: Condition of M_3—buccal side of posterior cone shows little or no wear, but in either case its crest is never below that of the lingual side. Both right and left teeth must conform.

The 3-, 4-, 5-, and 6-year-old specimens in the collection were checked for these five characters. If a character was present, it was recorded as positive; if absent, negative. The results are summarized in Table 5. The characters are considered alone or in combinations of three or five in the table. The

[b] These teeth varied from almost white to almost black, making it impossible to judge. Two specimens each had one I_4 missing (stage of eruption judged by I_4 present). A few were just through gum to about 50 per cent erupted. In some late specimens they were stained almost as much as the molars.

[c] For most specimens barely erupted (buccal crest on one side or both sides barely through gum).

number aged incorrectly indicates for 3-year-olds that the character in question was negative for these specimens (or in the case of combinations of three, at least two were negative; in combinations of five, at least three were negative). For the other year

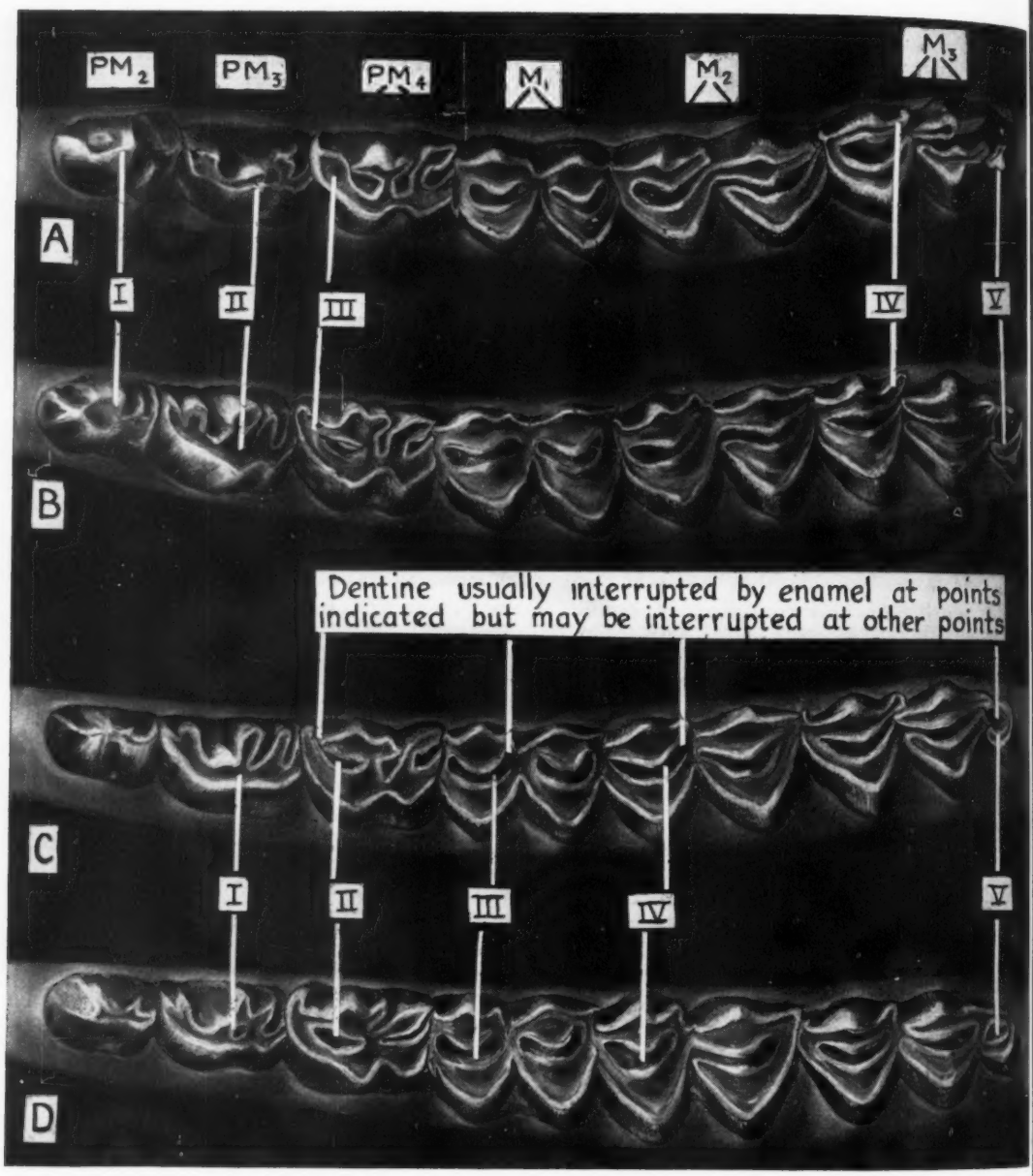


FIG. 2. Drawings of the occlusal surface of the left mandibular cheek teeth of the elk illustrating "three-" and "four-year-old" characters. **A**—Three-year-old showing all "three-year-old" characters positive. **B**—Four-year-old showing all "three-year-old" characters negative. **C**—Four-year-old showing all "four-year-old" characters positive (from two specimens). **D**—Five-year-old showing all "four-year old" characters negative.

TABLE 5.—EVALUATION OF "THREE-YEAR-OLD" CHARACTERS[1] FOR ESTABLISHING AGE OF ELK

Character	Number of Specimens and Number Aged Incorrectly by "Three-year-old" Characters											
	Three-year-old			Four-year-old			Five-year-old			Six-year-old		
	Types[2] and Number of Specimens		No. Aged[3] Incorrectly	Types[2] and Number of Specimens		No. Aged[4] Incorrectly	Types[2] and Number of Specimens		No. Aged[4] Incorrectly	Types[2] and Number of Specimens		No. Aged[4] Incorrectly
I	K	15	3	K	9	4	K	7	1	K	0	
	A	17	1	A	39	24	A	25	12	A	40	5
	T	32	4	T	48	28	T	32	13	T	40	5
II	K	15	10	K	9	0	K	8	0	K	0	
	A	17	10	A	39	1	A	25	1	A	40	0
	T	32	20	T	48	1	T	33	1	T	40	0
III	K	15	2	K	9	2	K	8	2	K	0	
	A	17	10	A	39	7	A	25	2	A	40	1
	T	32	12	T	48	9	T	33	4	T	40	1
IV	K	14	6	K	9	0	K	8	0	K	0	
	A	17	13	A	38	2	A	24	0	A	38	0
	T	31	19	T	47	2	T	32	0	T	38	0
V	K	15	1	K	9	2	K	8	0	K	0	
	A	17	2	A	39	7	A	25	0	A	40	0
	T	32	3	T	48	9	T	33	0	T	40	0
I II III IV V	K	15	2	K	9	1	K	8	0	K	0	
	A	17	6	A	39	1	A	25	1	A	40	0
	T	32	8	T	48	2	T	33	1	T	40	0
I II III	K	15	3	K	9	2	K	8	1	K	0	
	A	17	7	A	39	5	A	25	2	A	40	0
	T	32	10	T	48	7	T	33	3	T	40	0
I II IV	K	14	5	K	9	0	K	8	0	K	0	
	A	17	9	A	39	1	A	25	1	A	40	0
	T	31	14	T	48	1	T	33	1	T	40	0
I II V	K	15	4	K	9	1	K	8	0	K	0	
	A	17	3	A	39	4	A	25	1	A	40	0
	T	32	7	T	48	5	T	33	1	T	40	0
II III IV	K	14	5	K	9	0	K	8	0	K	0	
	A	17	13	A	39	1	A	25	1	A	40	0
	T	31	18	T	48	1	T	33	1	T	40	0
II III V	K	15	2	K	9	1	K	8	0	K	0	
	A	17	7	A	39	0	A	25	1	A	40	0
	T	32	9	T	48	1	T	33	1	T	40	0
III IV V	K	15	2	K	9	1	K	8	0	K	0	
	A	17	8	A	39	1	A	25	0	A	40	0
	T	32	10	T	48	2	T	33	0	T	40	0
I III IV	K	15	3	K	9	2	K	8	1	K	0	
	A	17	9	A	39	5	A	25	2	A	40	0
	T	32	12	T	48	7	T	33	3	T	40	0
I III V	K	15	1	K	9	2	K	8	1	K	0	
	A	17	3	A	39	7	A	25	2	A	40	0
	T	32	4	T	48	9	T	33	3	T	40	0
I IV V	K	15	2	K	9	1	K	8	0	K	0	
	A	17	2	A	39	5	A	25	0	A	40	0
	T	32	4	T	48	6	T	33	0	T	40	0
II IV V	K	14	5	K	9	0	K	8	0	K	0	
	A	17	8	A	39	2	A	25	0	A	40	0
	T	31	13	T	48	2	T	33	0	T	40	0

[1] Characters—*see* text.
[2] K=Known-age; A= Assigned-age; T=Total.
[3] Negative for the character(s) concerned.
[4] Positive for the character(s) concerned.

TABLE 6.—DEGREE OF ACCURACY FOR THE "THREE-YEAR-OLD" CHARACTERS AND COMBINATIONS WHICH ELIMINATED FIVE- AND SIX-YEAR-OLDS (BASIC DATA IN TABLE 5)

Characters	Per Cent Accuracy for		
	Three-year-olds[1]	Four-year-olds[2]	Three- and four-year-olds
IV	39	96	73
V	91	81	85
III IV V	69	96	85
I IV V	87.5	87.5	87.5
II IV V	58	96	81

[1] Positive for the character(s) concerned.

[2] Negative for the character(s) concerned.

classes the number aged incorrectly indicates the character(s) was positive for these specimens. When it was impossible to evaluate a character on the right or left side because of a damaged or missing tooth, it was evaluated on the basis of the undamaged tooth present (actually it makes no difference unless the character for the tooth evaluated was positive).

None of the characters either singly or in the various combinations eliminated all 4-year-olds (thus some 4-year-olds were positive for the "3-year-old" characters) but the following eliminated all 5- and 6-year-olds: IV; V; III, IV, V; I, IV, V; II, IV, V (no 5- or 6-year-olds were positive for these single characters or combinations). The degree of accuracy for these characters and combinations for 3-year-olds, for 4-year-olds, and for 3- and 4-year-olds combined is given in Table 6. The combination I, IV, V was superior to the others. Its use separated 87½ per cent of the 3-year-olds and 12½ per cent of the 4-year-olds into a group, 3 or 4 years old.

Hancock and Low (1956) state that, "With reasonable experience the 3½ year age group can in most instances be differentiated from the 4½ year-old animals. Generally speaking there is a progressive wear on both incisors and cheek teeth. The relative amount of wear on the cutting edge of incisors, premolars and particularly the wear on the posterior cusp of the third molar appears to be the best guide in separating the 3½ year-old group from older age classes. The relative degree of wear on the incisors appeared to be the least reliable criterion in separating 3, 4, and 5-year-old elk." They further state in the summary: "Elk can be accurately aged by the use of dental characteristics up to and including 3½ years of age. . . . Definite characteristics in elk dentition are present in the fall of the year during the hunting season which aid in classifying elk into . . . 3½ year- olds. . . ."

"Four-year-old Characters"

Five characters as illustrated in Fig. 2 and listed below were prominently represented in the 4-year-old specimens.

Character I: Condition of PM_3—no circle of enamel on occlusal surface about two-thirds of the distance back from anterior edge of tooth (circle results from wear; is therefore indicative of age). If circle is absent on both sides (teeth), record as positive. If present on one side (tooth) or both, record as negative.

Character II: Condition of PM_4—the infundibulum of the anterior cone not completely surrounded by dentine (interrupted by enamel)—uninterrupted dentine around infundibulum results from wear and is therefore indicative of age. If dentine is interrupted on both sides (teeth), record as positive. If dentine is uninterrupted on one side (tooth) or both, record as negative.

Character III: Condition of M_1—same as Character II but different tooth.

Character IV: Condition of M_2—same as Character II but different tooth.

Character V: Condition of M_3—same principle as Character II but here refers to posterior cone of M_3. (Characters II, III, IV, V obviously are to be recorded as negative if the infundibulum is competely worn out.)

The 3-, 4-, 5-, 6-, 7-, and 8-year-old specimens in the collection were checked for these five characters. If a character was

TABLE 7.—EVALUATION OF "FOUR-YEAR-OLD" CHARACTERS[1] FOR ESTABLISHING AGE OF ELK

Character	Number of Specimens and Number Aged Incorrectly by "Four-year-old" Characters																							
	Three-year-old			Four-year-old			Five-year-old			Six-year-old			Seven-year-old			Eight-year-old								
	No.[2, 3]		No.[4] Mis-aged	No.[2, 3]		No.[4] Mis-aged	No.[2, 3]		No.[5] Mis-aged	No.[2, 3]		No.[5] Mis-aged	No.[2, 3]		No.[5] Mis-aged	No.[2, 3]		No.[5] Mis-aged						
I	K	15	2	K	9	4	K	8	3	K	0		K	1	1	K	3	2						
	A	17	3	A	39	9	A	25	15	A	40	28	A	57	34	A	65	51						
	T	32	5	T	48	13	T	33	18	T	40	28	T	58	35	T	68	53						
II	K	15	1	K	9	2	K	8	3	K	0		K	1	0	K	3	0						
	A	17	0	A	39	10	A	25	13	A	40	16	A	57	7	A	65	8						
	T	32	1	T	48	12	T	33	16	T	40	16	T	58	7	T	68	8						
III	K	15	13	K	9	7	K	8	1	K	0		K	1	0	K	3	0						
	A	17	14	A	39	36	A	25	1	A	40	1	A	57	0	A	65	0						
	T	32	27	T	48	43	T	33	2	T	40	1	T	58	0	T	68	0						
IV	K	15	0	K	9	3	K	8	2	K	0		K	1	0	K	3	0						
	A	17	2	A	39	15	A	25	16	A	40	12	A	57	2	A	65	1						
	T	32	2	T	48	18	T	33	18	T	40	12	T	58	2	T	68	1						
V	K	15	0	K	9	2	K	8	4	K	0		K	1	0	K	3	0						
	A	17	0	A	39	1	A	25	16	A	40	20	A	57	9	A	65	0						
	T	32	0	T	48	3	T	33	20	T	40	20	T	58	9	T	68	0						
I II III IV V	K	15	0	K	9	2	K	8	3	K	0		K	1	0	K	3	0						
	A	17	0	A	39	10	A	25	12	A	40	10	A	57	4	A	65	0						
	T	32	0	T	48	12	T	33	15	T	40	10	T	58	4	T	68	0						
I II III	K	15	2	K	9	3	K	8	1	K	0		K	1	0	K	3	0						
	A	17	3	A	39	15	A	25	10	A	40	11	A	57	4	A	65	6						
	T	32	5	T	48	18	T	33	11	T	40	11	T	58	4	T	68	6						
I II IV	K	15	0	K	9	2	K	8	3	K	0		K	1	0	K	3	0						
	A	17	0	A	39	9	A	25	14	A	40	19	A	57	5	A	65	7						
	T	32	0	T	48	11	T	33	17	T	40	19	T	58	5	T	68	7						
I II V	K	15	0	K	9	2	K	8	4	K	0		K	1	0	K	3	0						
	A	17	0	A	39	4	A	25	14	A	40	22	A	57	11	A	65	6						
	T	32	0	T	48	6	T	33	18	T	40	22	T	58	11	T	68	6						
II III IV	K	15	0	K	9	3	K	8	1	K	0		K	1	0	K	3	0						
	A	17	2	A	39	22	A	25	8	A	40	4	A	57	1	A	65	0						
	T	32	2	T	48	25	T	33	9	T	40	4	T	58	1	T	68	0						
II III V	K	15	0	K	9	3	K	8	3	K	0		K	1	0	K	3	0						
	A	17	0	A	39	10	A	25	9	A	40	7	A	57	3	A	65	0						
	T	32	0	T	48	13	T	33	12	T	40	7	T	58	3	T	68	0						
III IV V	K	15	0	K	9	4	K	8	2	K	0		K	1	0	K	3	0						
	A	17	2	A	39	16	A	25	10	A	40	7	A	57	1	A	65	0						
	T	32	2	T	48	20	T	33	12	T	40	7	T	58	1	T	68	0						
I III IV	K	15	2	K	9	4	K	8	1	K	0		K	1	0	K	3	0						
	A	17	5	A	39	18	A	25	12	A	40	10	A	57	2	A	65	1						
	T	32	7	T	48	22	T	33	13	T	40	10	T	58	2	T	68	1						
I III V	K	15	2	K	9	4	K	8	2	K	0		K	1	0	K	3	0						
	A	17	3	A	39	9	A	25	9	A	40	16	A	57	8	A	65	0						
	T	32	5	T	48	13	T	33	11	T	40	16	T	58	8	T	68	0						
I IV V	K	15	0	K	9	2	K	8	3	K	0		K	1	0	K	3	0						
	A	17	0	A	39	5	A	25	17	A	40	19	A	57	9	A	65	1						
	T	32	0	T	48	7	T	33	20	T	40	19	T	58	9	T	68	1						
II IV V	K	15	0	K	9	2	K	8	4	K	0		K	1	0	K	3	0						
	A	17	0	A	39	4	A	25	17	A	40	12	A	57	5	A	65	0						
	T	32	0	T	48	6	T	33	21	T	40	12	T	58	5	T	68	0						

[1] Characters—*see* text.

[2] K=Known-age; A=Assigned-age; T=Total.

[3] When it was impossible to evaluate a character on the right or left side because of a damaged or missing tooth, it was evaluated on the basis of the undamaged tooth present (actually it makes no difference unless the character for the tooth evaluated was positive).

[4] Negative for character(s) concerned.

[5] Positive for character(s) concerned.

TABLE 8.— DEGREE OF ACCURACY FOR THE "FOUR-YEAR-OLD" CHARACTERS AND COMBINATIONS WHICH ELIMINATED EIGHT-YEAR-OLDS (BASIC DATA IN TABLE 7)

Characters	Per Cent Accuracy for					
	Three-[1] year-olds	Four-[1] year-olds	Five-[2] year-olds	Six-[2] year-olds	Seven-[2] year-olds	3-4-5-6-7-year-olds
V	100	94	39	50	84	75
I II III IV V	100	75	55	75	93	81
II III IV	94	48	73	90	98	81
II III V	100	73	64	82.5	95	83
III IV V	94	58	64	82.5	98	80
I III V	84	73	67	60	86	75
II IV V	100	87.5	36	70	91	79
III	16	10	94	97.5	100	65

[1] Positive for the character(s) concerned.

[2] Negative for the character(s) concerned.

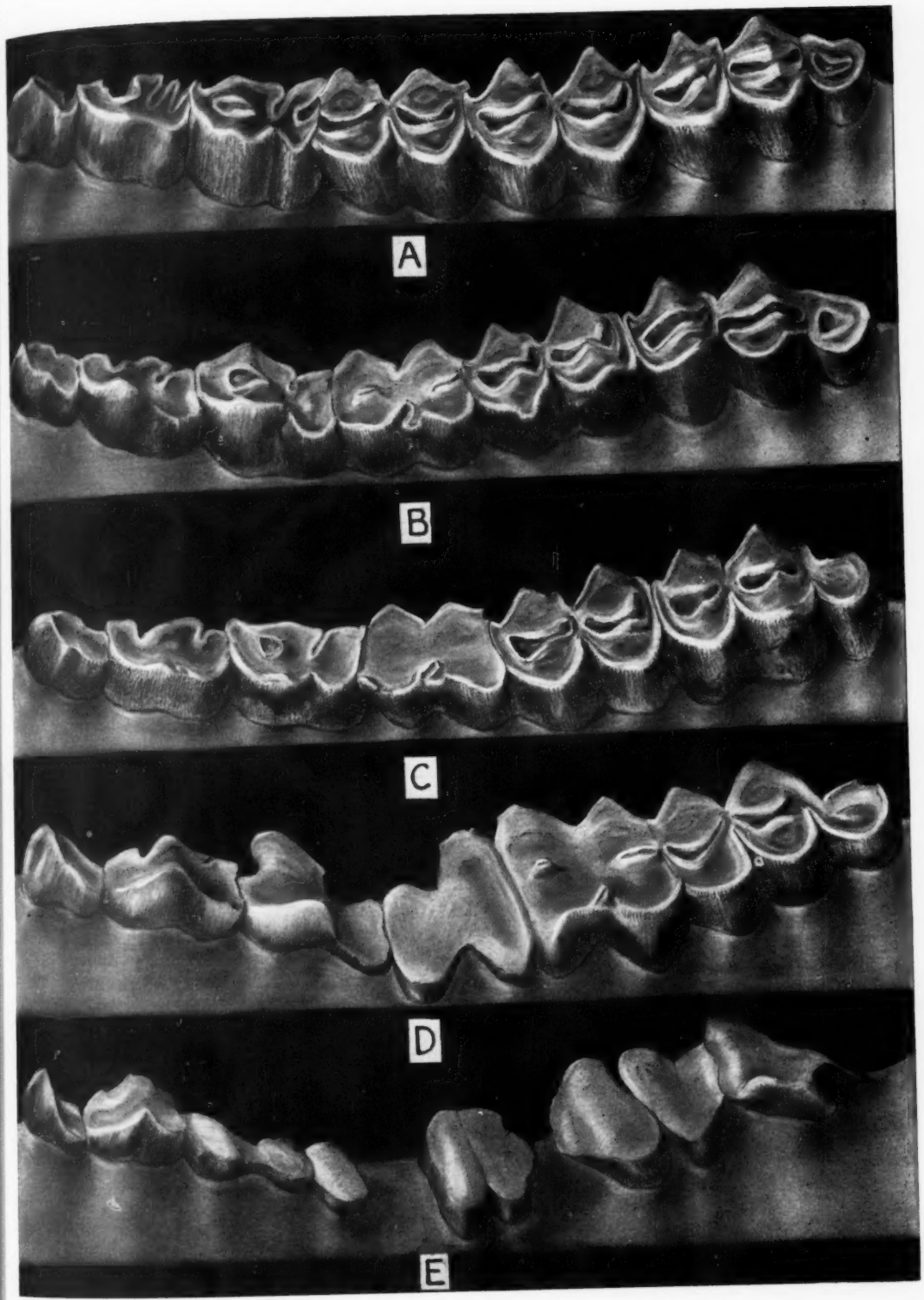
present, it was recorded as positive; if absent, negative. The results are summarized in Table 7. The characters are considered alone or in combinations of three or five in the table. The number aged incorrectly indicates for 3- and 4-year-olds that the character in question was negative for these specimens (or in the case of combinations of three, at least two were negative; combination of five, at least three were negative). For the remaining year classes the number aged incorrectly indicates the character(s) was positive for these specimens.

None of the characters either singly or in the various combinations eliminated 5- or 6-year-old specimens (thus some 5- and 6-year-olds were positive for the "4-year old" characters). Character III eliminated 7- and 8-year-olds (no 7- or 8-year-old was positive for this character). The following eliminated all 8-year-olds: V; I, II, III, IV, V; II, III, IV; II, III, V; III, IV, V; I, III, V; and II, IV, V. The degree of accuracy for these characters and combinations for 3-year-olds (under 5), for 4-year-olds, for 5-year-olds, for 6-year-olds, for 7-year-olds, and for 3-, 4-, 5-, 6-, and 7-year-olds combined is given in Table 8. The combination II, III, V appeared to be of more value than any of the others. Its use separated 100, 73, 36, 17½, and 5 per cent of 3-, 4-, 5-, 6-, and 7-year-olds, respectively, into a group: 3-, 4-, 5-, 6-, or 7-years-old. This group was further broken down by use of the "3-year-old" characters which separated 87½ per cent of the 3-year-olds and 12½ per cent of the 4-year-olds into the 3- or 4-year-old group.

AGING BY VISUAL IMPRESSIONS

Aging of elk jaws by comparison with assigned-age specimens on a jaw board also indicated variations within year classes. Five graduate students with no previous experience "aged" all known-age jaws (except calves, yearlings, and 2-year-olds which are readily recognized) in the collection by this method. Eleven of fifteen 3-year-olds were aged correctly; the other four were aged as 4-year-olds. Seven of nine 4-year-olds were aged correctly; one was aged as 3-, the other as 6-. For eight 5-year-olds the results were: seven aged correctly and one aged as 7-. The one 7-year-old was aged correctly. With more experience the above students undoubtedly would improve their accuracy. The senior author aged the same specimens hurriedly by visual impression only (without the aid of the jaw board) as follows: all fifteen 3-year-olds correctly; seven of nine 4-year-olds correctly (but two were discounted because the author recognized the specimens), one was aged as a

FIG. 3 (right). Natural-size drawings (side-occlusal view) of the mandibular cheek teeth of the elk. **A**—Seven-year-old. **B**—Eight-year-old. **C**—Nine-year-old. **D**—Fifteen-year-old. **E**—Twenty-one-year-old.


A
B
C
D
E

5- and the other a 3-; two of eight 5-year-olds were erroneously aged as 4-year-olds, the others were aged correctly; the 7-year-old was incorrectly aged as an 8-year-old.

It appears that age classes vary one from the other more than is indicated by the specific characters. Many of the differences, however, are not readily amenable to quantitative measurements.

DISCUSSION AND CONCLUSIONS

The data indicate that age classes (calves, yearlings, 2-year-olds) that have not attained a full complement of completely erupted permanent mandibular teeth can be aged with confidence. Determination of age classes (three years and older) with a full complement of completely erupted permanent mandibular teeth by characters indicative of wear is subject to definite limitations. It would appear that the chances of aging specimens of this latter group with accuracy decreases with the animals' age. It could be argued that the authors failed to select the best characters for expressing wear, but the characters used are indicative of wear (e.g., note that 100, 73, 36, 17½, and 5 per cent of the 3-, 4-, 5-, 6-, and 7-year-olds, respectively, are positive for combination II, III, V of "4-year-old characters").

The aging of jaws by comparison with assigned-age jaws on a jaw board apparently gives more accurate results than aging by specific characters, but inaccuracies with this method can also be expected (note that some specimens were erroneously aged by as much as two years).

Familiarity gained by handling large numbers of jaws seems to provide the best criteria for establishing age classes.

The following aging techniques are recommended in the order of their apparent accuracy: (1) direct comparison with known-age jaws, (2) comparison with assigned-age jaws, and (3) comparison with good drawings or photographs of known-age jaws. Attempts should be made to place each specimen in its proper year class. Obviously some specimens of the older age classes (those with "full mouth") will be improperly aged but some will be over aged and some under aged. Errors would have a tendency to average out, thus giving a fairly reliable determination of percentage composition by age classes of the sample. Conclusions on the age of an individual specimen with "full mouth" should be viewed with caution. Robinette, *et al.* (1957) arrived at similar conclusions concerning aging of mule deer (*Odocoileus hemionus*). They state: "We feel that the chart offered . . . and the photographs . . . do not permit positive aging except with rather low probabilities. Their prime use lies in determining percentage composition by age classes of deer killed by hunters or other factors. In age assignments of this kind, where a large number of specimens are involved, the errors should tend to be compensating providing, of course, the aging criteria are representative."

SUMMARY

The mandibular dentition of 168 known-age (½- to 21-years-old) and 527 assigned-age elk constituted the basis for an aging study. Calves, yearlings, and 2-year-olds were readily segregated on the basis of types (deciduous or permanent), number, and stage of eruption of teeth. The calf was readily recognized by the dental formula $DI_{1,2,3,4}$ $DM_{2,3,4}$ $M_1 \times 2$. The yearling dental formula was variable but only for the first two teeth. I_1 $DI_{2,3,4}$ $DM_{2,3,4}$ $M_{1,2} \times 2$ and $I_{1,2}$ $DI_{3,4}$ $DM_{2,3,4}$ $M_{1,2} \times 2$ were encountered most often, with the former predominating in October–January specimens and the latter in February and April specimens. The dental formula for 2-year-olds showed considerable variation as concerns chiefly the deciduous molars and/or premolars and also the incisors but it can be used to separate this group from yearlings. The presence of 6 to 8 permanent incisors and molar three is conclusive. Most 2-year-olds had at least 1 premolar. The premolars replace the deciduous molars during an animal's third fall and/or winter.

Elk older than two years had complete permanent mandibular dentition which separated these animals from 2-year-olds that retained any of the milk dentition. For 2-year-olds that had lost all milk dentition, the condition of certain teeth was characteristic. The recently erupted premolars were lighter in color than the accompanying molars (one exception). The third cone of M_3 was not completely erupted for any specimen examined.

Wear on the mandibular cheek teeth appeared to provide the best criterion for aging elk with a "full mouth." Only characters thought to be indicative of wear and amenable to quantitative expression were considered. Five characters representing four mandibular cheek teeth were prominently represented in the 3-year-old specimens; and 3-, 4-, 5-, and 6-year-old specimens were checked for these five characters. None of the characters either singly or in various combinations eliminated all 4-year-olds. The best combination separated 87½ per cent of the 3-year-olds and 12½ per cent of the 4-year-olds into a group: 3 or 4 years old.

Five characters representing five mandibular cheek teeth were prominently represented in the 4-year-old specimens; and 3-, 4-, 5-, 6-, 7-, and 8-year-old specimens were checked for these five characters. The best combination separated 100, 73, 36, 17½, and 5 per cent of the 3-, 4-, 5-, 6-, and 7-year-olds, respectively, into a group: 3, 4, 5, 6, or 7 years old.

Aging of elk jaws by comparison with specimens on a jaw board also indicated variation within year classes but not so great as indicated by use of the specific characters.

Despite the limitations of aging individual specimens with "full mouth," age-class data for hunter kills and other samples should be secured by: (1) direct comparison with known-age jaws, (2) comparison with assigned-age jaws, or (3) comparison with good drawings or photographs of known-age jaws. Obviously, some specimens with "full mouth" will be improperly aged, but some will be over and some under aged. Errors would have a tendency to average out, thus giving a fairly reliable determination of percentage composition by age classes of the sample.

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BRIEFER ARTICLES

A BETTER SNOWSHOE HARE LIVE TRAP

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During work in both Maine and Alaska, the writer has observed a desire on the part of biologists to have an efficient trap for catching snowshoe hares (*Lepus americanus*). The following is a description of a double-ended trap designed by Howard L. Jackson (deceased), a professional trapper from Dexter, Maine, who used these traps to capture large numbers of snowshoe hares for export to other states, when this was legal. The trap has proven satisfactory to biologists in both Maine and Alaska.

The approximate over-all dimensions of the trap illustrated in Fig. 1 are: length, 30 inches; width, 11 inches; and height, 12 inches. The frame of the trap is constructed of 1- by 1.5-inch wood strips; the floor, roof, door stops, and side boards can be of any thin light material such as shingles, clapboards, or plywood. The doors are made of 9-inch lengths cut from 1- by 8-inch board; each door is hinged and closed by a single spring screen-door hinge. The sides are covered with 1.5-inch-mesh galvanized chicken wire, or similar screening. The treadle or trigger is a section of thin board that fits in the bottom of the trap and is long enough so that it engages about three-fourths of an inch of the bottom edge of both doors when they are open. Approximately 1 inch should be left between the bottom of the doors and the floor of the trap to allow the doors to pass over the treadle when the trap is sprung. The treadle can be either hinged or loose, but space should be left beneath it so that it pivots freely and the possibility of dirt or snow getting stuck under it is reduced. A one-half-inch-square strip nailed to the bottom of the pivot edge of the treadle will suffice as a fulcrum.

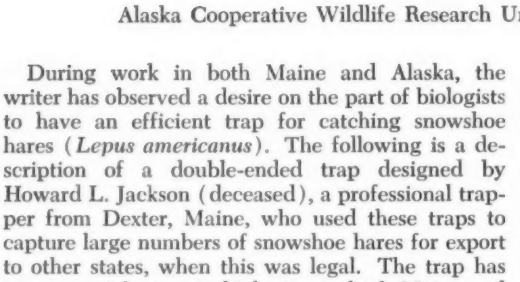

FIG. 1. Trap in set position
1. Door
2. Treadle
3. Side board
4. Door stop

The trap is set by opening both doors and lifting the free side of the treadle far enough to hold both doors open at the same time. The tension of the springs in the door hinges holds the treadle in the set position until the weight of the hare pushes the treadle off the bottom edge of the doors thereby releasing them so that they spring closed. If desired, hooks made of stiff wire may be attached to the sides in a convenient place to hold the doors open as an aid in setting the trap and in removing hares.

The trap is designed for winter use and works well in snow. The solid floor serves to keep snow from blocking the treadle when the trap is placed in the snow, and the solid roof keeps falling snow from filling and blocking the trap. The trap may be rendered inoperative by blowing snow filling in between the floor and the treadle or by alternate thawing and freezing weather causing the doors and the treadle to freeze together. The trap weighs from 8 to 10 pounds depending upon the material of which it is made, but can be transported easily by toboggan or sled. Joseph Dell (1956, New homes for hares. N.Y. State Conservationist, 10[5]:6–7) illustrates an operation using a similar trap with drop doors rather than spring-closed ones. The present trap probably evolved from the drop-door type, and is a distinct improvement as the spring-closed doors operate more rapidly and are less affected by weather conditions than are the drop doors.

The cost of materials is approximately $2.00 per trap, and construction requires about one hour. With proper care such as oiling the springs and storing out of the weather when not in use, the traps can be used for several years.

The trap is set in or near rabbit trails and is baited by placing a quantity of the preferred browse of the area [yellow birch (*Betula lutea*) in Maine, and aspen (*Populus* spp.) in Alaska] around and over the trap, care being taken to leave the entrances clear. Branches of an unpalatable species or dead sticks may be used to fence the bait in such a manner that the hare will enter the trap in trying to reach the food, which can be seen through the wire sides. To date, no difficulty has been encountered from predators, but weasels could easily get through the chicken wire. If predation by weasels is anticipated, hardware cloth should be used for the sides.

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A DEVICE FOR HOLDING RABBITS DURING X-RAY PHOTOGRAPHY

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X-ray photographs are used extensively for investigating epiphyseal fusion to indicate the age of rabbits. In American research work the live animals were apparently held in position over the X-ray plate by hand (Thomsen and Mortensen, 1946; Hale, 1949; Petrides, 1951). Later, in New Zealand, Tyndale-Biscoe devised a strait jacket for holding the rabbits (*Oryctolagus cuniculus* L.) to avoid exposing the operators to radiation (Watson and Tyndale-Biscoe, 1953).

The strait jacket was designed to hold rabbits of different sizes and to obtain different views of the leg bones. However, after being fastened, the rabbit could, by flexing or relaxing the muscles, alter the position of the leg. The changed position was not obvious until the plate had been developed, and repeat exposures, with a resulting waste of time and material, were necessary to ensure a series of pictures presenting similar views. It was found that a lateral view was sufficient, and further work by the Animal Ecology Section in New Zealand's Department of Scientific and Industrial Research led to the design of a more suitable rabbit holder.

The device was made to restrain the left hind leg, so that a lateral view of the knee joint could be obtained. Fig. 1 shows the rabbit in the finished holder, ready for exposure. The foot and lower part of the leg rest in a groove at the base of the holder. Twisting of the leg is prevented by the angle at which the foot is held by a removable peg. The pelvis is held between the back of the holder and a buttress by a leather strap around the upper part of the right leg. The forequarters fit into a closely woven bag. There is less tendency for the rabbit to struggle when the eyes are covered, and the loose-fitting bag does not interfere with breathing.

Three-ply wood is used for the back-board, base-board and upper side of the shaped groove. A spacer, cut to shape as shown in Fig. 2, is built up to suitable thickness with layers of ply wood. The upper side of the groove has been removed for the purpose of illustration; in normal use it remains fixed. An L-shaped bracket of ½-inch thick pine gives extra rigidity to the back-board, and serves as an anchorage for the broad end of the leather strap. The buttress (Fig. 1) is of ¾-inch thick pine. The base and back-board were assembled first in order to obtain the dimensions of the groove and positions of the bracket and buttress. A rabbit was held in the desired position, and pencil-marks made for guidance. Fig. 2 also shows the catch, made of spring wire, which holds the narrow end of the strap. The lower end of this is turned into the wood to prevent twisting, and two wire staples hold it securely. Throughout construction no specialised joints are used; screws and small nails are sufficient. All projections are rounded, and the holder given two coats of spar varnish to give a hard, smooth surface less likely to collect dirt. The over-all dimensions of the finished device are 24 × 6 × 6¼ inches and the weight just under 4 pounds.

The use of this holder results in clearer photographs being obtained with a considerable saving of time. With it, one technician can handle five

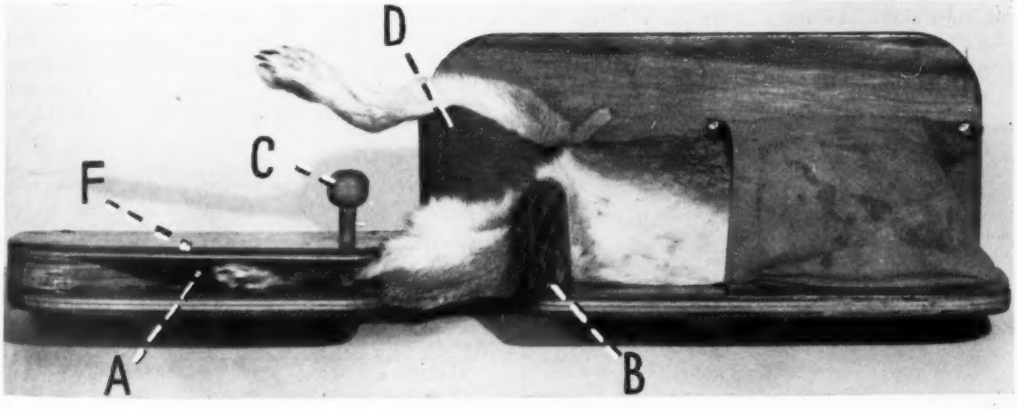

FIG. 1. Front view of holder.

A—groove for leg; B—buttress; C—removable peg; D—leather strap; F—upper side of grove. (Photo S. N. Beatus)

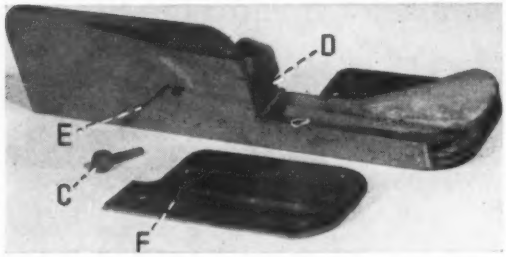

FIG. 2. Back view of holder. C—removable peg; D—leather strap; E—catch; F—upper side of groove. (Photo S. N. Beatus)

rabbits in five minutes, whereas with Tyndale-Biscoe's strait jacket an average time of three minutes was needed per rabbit. There is no obstruction between the subject and the X-ray plate. Apart from their usual aversion to being handled, the animals do not appear to suffer any discomfort.

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RESULTS OF A WOODCHUCK CONTROL EXPERIMENT

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As no published data are available in the literature regarding the control of woodchucks (*Marmota monax*) using the cartridge developed by the U.S. Fish and Wildlife Service, the authors consider it useful to describe a control experiment made on a farm of the Ontario Agricultural College near Guelph, Ontario, during the period May 7–10, 1956.

The woodchuck cartridge (Fig. 1) is about 3½ inches long and 1½ inches in diameter, and is filled with a powder which produces poisonous gases when ignited by a fuse. These gases include carbon monoxide, oxides of sulphur and nitrogen and one of the phosphorus compounds. The cartridge is inserted well down into a burrow, and this burrow and other holes belonging to the same system are subsequently closed with sod to prevent gases from escaping.

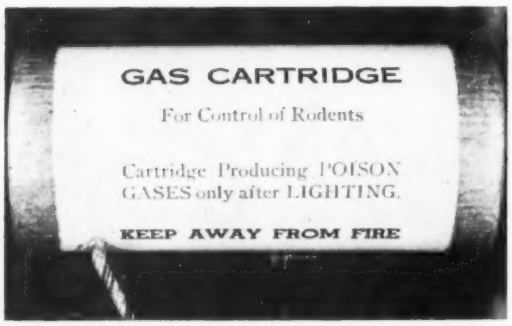

FIG. 1. Gas cartridge for the control of burrowing rodents (photo by J. C. Ward).

The objective of the experiment was to eliminate entirely the woodchuck population in a field of 18.6 acres. In order to accomplish this and, if possible, to eliminate influx from surrounding fields, it was considered necessary to treat a total area of about 100 acres, of which this field was roughly the center. Although burrows on the College farms are treated annually by using the exhaust fumes of tractors, considerable woodchuck activity was noticeable on the area to be treated.

The field method in this experiment involved three individuals who walked parallel strips and jointly treated the various burrows. One person recorded the location of burrows, the number of cartridges ignited and the observations concerning woodchucks. Fig. 2 shows the treated area, as well as the location of the various burrows and the woodchucks sighted. Table 1 summarizes the various treatments during the period May 7 to 10. Nine

TABLE 1.—TREATMENTS OF WOODCHUCK BURROWS IN A 100-ACRE AREA

Date of Treatment	No. of Treatments in Control Field of 18.6 Acres	No. of Burrows Re-treated	Total No. of Treatments in 100-acre Area	No. of Cartridges Which Misfired
May 7	31		42	1
May 8	3	3	82	8
May 9	0	10	33	0
May 10	1	4	9	0
Totals	35	17	166	9

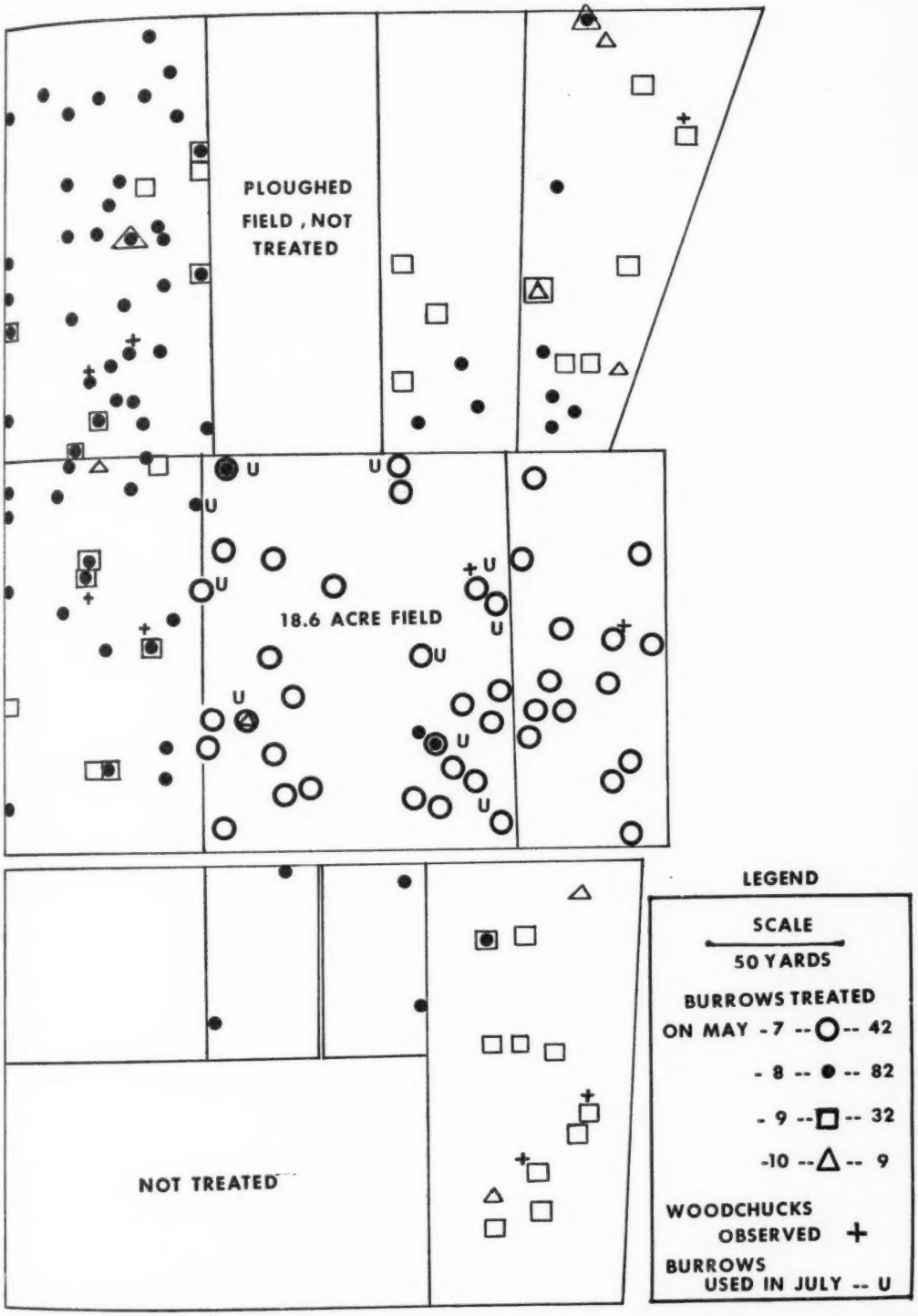

FIG. 2. Map of the treated area, showing the location of the treated burrows.

cartridges misfired, or 5 per cent of the total used.

In total, 17 burrows required retreatment on the next or subsequent days. It may be noticed that on May 9th a fair number of burrows were treated which were missed on the previous day. Undoubtedly a few burrows were overlooked nevertheless.

Twelve woodchucks were observed in the 100-acre area from May 7 to 9. None were seen on the last day of treatment.

On May 23 the 18.6-acre field was revisited, and four burrows were found to be opened up, two of which indicated recent burrowing activities of woodchucks. No woodchucks were sighted. Nine recently used burrow systems and one woodchuck were noticed on July 11, and eleven burrow systems were in use on July 23 (Fig. 2). This means that more than one-third of the burrows were opened up again. The field was plowed up immediately after July 23. A visit on September 26 disclosed that none of the burrows which had been plowed down were opened up. However, there were indications of possible use in three burrows situated along the fences.

The three visits made after the control experiment was discontinued indicate relatively high woodchuck activity. There are two possible explanations for this: first, that a relatively rapid influx took place from the surrounding fields which were not controlled; and second, that a certain number of woodchucks survived treatment. This second alternative seems to us improbable. Considering the size of the area treated, we feel that it would not take the average woodchuck very much time to infiltrate into the center field.

Whatever the causes for woodchuck activity during late May and July may be, the results do not appear to be satisfactory. This implies the need for more controlled experiments and for more fundamental knowledge of the biology of the species.

In total, 40 man hours were spent on the project. Since an ordinary control operation requires only one man, and since a fourth visit, such as we made on May 10, may not be necessary under average conditions, we estimate that one man could have done the operation in about 24 hours. If the average farmer earns $1.00 per hour, this would amount to $24.00. One hundred and sixty-six cartridges, selling at $0.065 each, would cost $10.78. The total expenditure for the operation would therefore be about $34.78, or approximately $0.35 per acre. Considering the results obtained, it is doubtful that this investment is warranted except in areas of valuable truck crops, orchards, etc.

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AN AUTOMATIC NEST-TRAP FOR WATERFOWL[1]

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The study of renesting, migrational homing, and other aspects of breeding behavior in waterfowl often necessitates trapping females on their nests for marking. Sowls (1950) successfully used a manually tripped drop net and a hand net and Harris (1952) used a throw net for capturing ducks nesting on land. These methods are less efficient for trapping diving ducks that usually nest over water in tall vegetation. Moreover, most species of divers are innately less broody than dabblers and cannot be approached as easily while they are incubating.

During the course of a recent study of the breeding biology of the redhead (*Aythya americana*) in Manitoba and Utah, the writer modified the Sowls drop trap for use on nests located over water. In order that the vegetation would not interfere with the operation of the trap, its size was reduced to a circular frame 12 to 14 inches in diameter which enclosed only the bowl and rim of the nest. Cotton netting of one-inch mesh was used instead of wire. Although the trap was used successfully, it was not efficient, for it was almost essential that the observer see the position of the hen on the nest before releasing the trap; thus a blind was necessary and trapping attempts were tedious and often futile.

It became apparent that an automatic trap was necessary to capture diving ducks efficiently. Automatic nest traps have been avoided by waterfowl workers, apparently because of the fear of causing nest desertion and egg breakage. In fact, Lincoln (1947:49) issued a general warning against their use. Nevertheless, they have been used successfully on passerines (R. A. McCabe, personal communication), gulls (Griffin, 1943), and doves (Swank, 1952).

A simple automatic trap was constructed from 14-gauge galvanized welded wire fencing (1- × 2-inch mesh) with an entrance 5 to 6 inches wide and 8 to 12 inches high. A sliding drop door, also of 1- × 2-inch welded fencing, was guided by two pieces of 9-gauge wire. The roof was made of welded wire, but cotton netting of small enough mesh to prevent entanglement of the duck's head would be satisfactory. The door was released when the female depressed a treadle connected to the door-release pin by a string, as shown in Fig. 1.

[1] Contribution from the Delta Waterfowl Research Station and the Missouri Cooperative Wildlife Research Unit: U.S. Fish and Wildlife Service, Wildlife Management Institute, Missouri Conservation Commission, Edward K. Love Foundation, and University of Missouri cooperating.

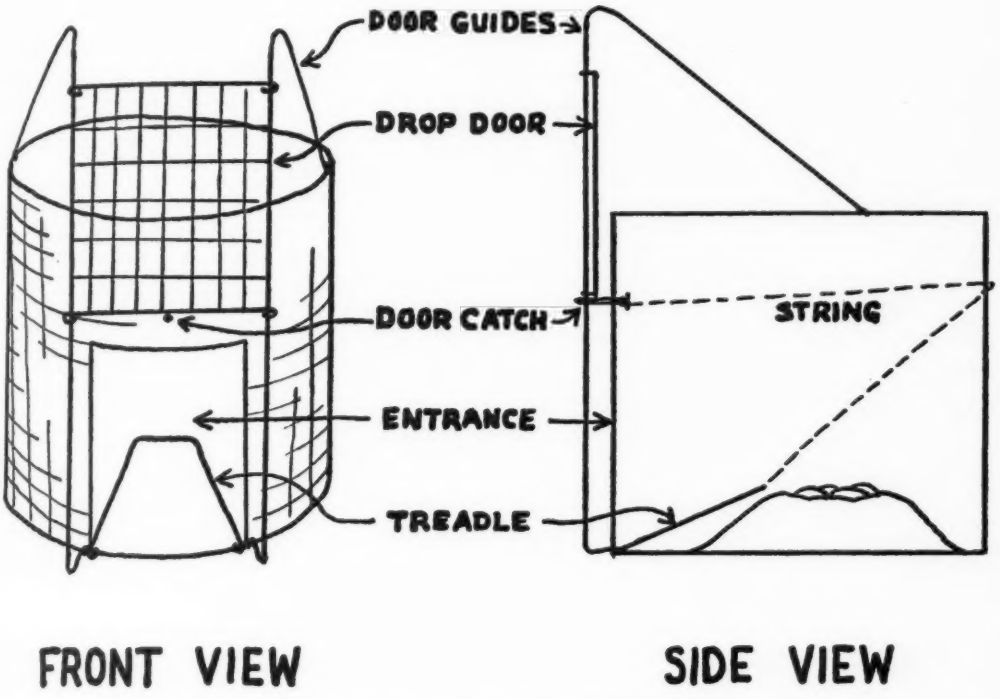

FIG. 1. Automatic trap used to capture female diving ducks on the nest.

The size of the trap depended on the species to be captured and the location of the nest. A trap 14 inches high and 16 inches in diameter was found to be most useful for diving ducks nesting on mounds of vegetation surrounded by water. For ducks nesting on land, a trap 8 to 10 inches high can be used because their nests are often in shallow depressions in the ground. Traps of larger diameter (24 to 26 inches) were advantageous for nests on land, however, because captured hens could retreat from the nest to the rear of the trap as the observer approached—thus their attempts to escape did not damage the eggs.

In order to prevent desertion by the hen, the trap was used only on nests in which the eggs had been incubated for at least two weeks; stages of incubation were determined by use of a field candler (Weller, 1956).

The procedure for trapping was as follows. The trap was staked to the base of the nest with the door facing the side most used by the female when entering the nest. This side could be identified by its prominent ramp, which led through an obvious opening in the vegetation. Next, a pad of nest material was placed over the top of the eggs in an added attempt to prevent breakage by the captured hen. The trap was left open for 15 to 45 minutes, depending on the broodiness of the female, and the nest area was watched from a distance whenever possible. However, some traps were left for several hours without causing mortality.

In the writer's study, the following birds were captured during incubation: six redheads, five canvas-backs (*Aythya valisineria*), three mallards (*Anas platyrhynchos*), and one cinnamon teal (*A. cyanoptera*). In addition, one female mallard was captured late in her laying period. Only two trapping attempts were unsuccessful; one probably failed because the door of the trap was placed on the wrong entrance ramp and one because the female was not yet sufficiently broody.

Eggs of the trapped females were removed from the nests to study renesting. Thus it was not determined whether hens captured with this trap would return to incubate their eggs. However, H. F. Duebbert captured four incubating gadwalls (*Anas strepera*) with this trap at the Lower Souris Refuge and did not remove their eggs; three of the four hens returned and hatched their eggs.

One of the major uses of the trap by the author was to capture female redheads that were laying parasitically in the nests of other ducks. Forty-two such females were captured by setting up five traps on mallard nests and examining them two or three times daily.

No mortality was caused by the trap, but occasionally parasitizing females damaged their bills slightly in trying to escape. Brooding hens observed

in the traps incubated their eggs and did not attempt escape until the investigator approached the nest.

If an investigator traps females late in the incubation period and examines the traps at regular intervals, a very high catch success should be possible without loss of hens or their eggs.

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AVIAN RECOVERIES FROM MUTILATING ACCIDENTS TO BOTH LEGS

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The accompanying photograph (Fig. 1) of an adult female gadwall (*Anas strepera*), shot in flight near the Quill Lakes in central Saskatchewan in the fall of 1956, illustrates a remarkable recovery from the loss of almost the entire left foot and the toes and webs of the right. So little of the toes remained that it is very unlikely the bird was able to stand. The breast feathers were much worn in one area, probably from resting upon them or rubbing along the ground when the bird attempted to walk. The legs were completely healed, so the accident, or accidents must have occurred very early in the spring, perhaps on the wintering ground, possibly even in a previous season. The accidents could have taken place in different years. Although thin, there was nothing in its flight to indicate that the bird was other than normal. The large numbers of ducks handled in mass banding drives during the flightless period of the eclipse show recovery from the loss of one foot to be not uncommon. This is the first waterfowl survival from such serious injury to both limbs to come to our attention.

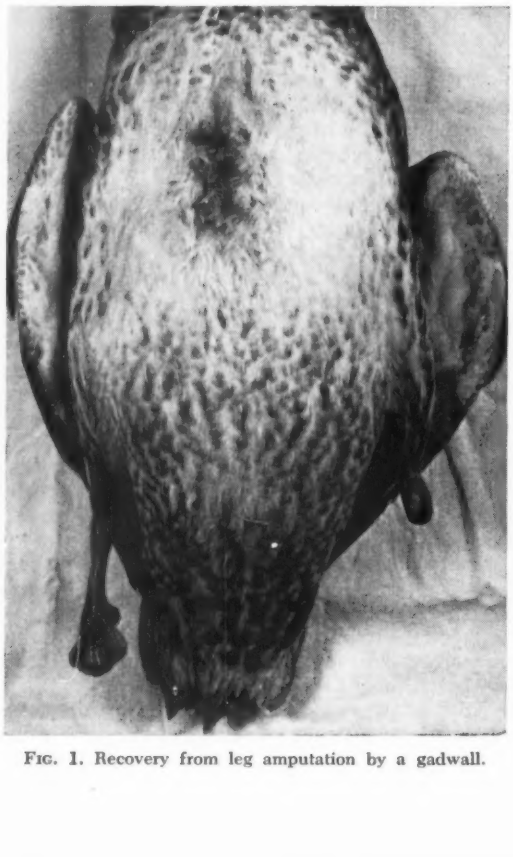

FIG. 1. Recovery from leg amputation by a gadwall.

Amputation of one leg is of uncommon but regular incidence among hen pheasants (*Phasianus colchicus*) in the Lake States, the phenomenon being generally attributable to contact with haymowing machinery. On October 28, 1946 a hen

FIG. 2. Recovery from leg amputation by a pheasant.

with both legs mutilated (Fig. 2) was shot (illegally) on a public hunting ground in Wisconsin. According to N. R. Barger (pers. comm.), a cock with both legs amputated was shot in 1956 in Winnebago County in the same state. Despite this handicap, the bird was reported to be a fast runner.

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BLACK LOCUST FOR QUAIL IN MASSACHUSETTS

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Detailed studies involving fall-through-spring covey counts and ranging habits of the bob-white quail (*Colinus virginianus*) were conducted on a 1,600-acre study area in Barnstable County (Cape Cod), Massachusetts, for three years, 1953–54 through 1955–56. The area is generally typical of the northeastern Atlantic coastal region in composition and distribution of cover types. Direct observations, frequently taken under snow conditions, clearly showed that the seed of black locust (*Robinia pseudoacacia*) constituted the main food item for 65 per cent (19 of 29) of all coveys that wintered in the Barnstable area during the three-year period. All of these coveys showed satisfactory (approximately 50 per cent) over-wintering survival.

Coveys were observed to be immediately attracted by seed-bearing limbs that had been broken off by storms. Once the easily obtained seed was consumed, the birds flew up to the persistent pods (often 10 or more feet high), ripping and dislodging the fruit.

Many locust stands, used by quail, have well-developed shrub strata of tartarian honeysuckle (*Lonicera tatarica*). Such areas provide dense cover that is remarkably free of herbaceous growth. Preference for stands with typically "clean bottoms" under the shrub strata of honeysuckle was observed (where a choice existed). Probably the dense cover and the relative ease of scratching for the locust seed combined to make these areas more attractive.

In addition to their value to quail, black locust stands, particularly with the honeysuckle shrub stratum, were favored areas for woodcock (*Philohela minor*). Probe marks, splashings and the presence of the birds themselves demonstrated their attraction to these covers.

Although locust seed has been given a low rating as a food for quail (Leopold, 1933:261; Martin, Zim, and Nelson, 1951:333), our observations suggest that the black locust-tartarian honeysuckle combination is worthy of serious testing as a management tool.

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[1] Present address: Virginia Cooperative Wildlife Research Unit, Biology Department, V. P. I., Blacksburg, Virginia.

[2] A contribution of Federal Aid Project, W-25-R.

A CALCULATOR FOR HANDLING LARGE SERIES OF AGED-BROOD DATA

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Duck-production studies have been greatly aided by recently developed techniques for censusing and aging broods (Blankenship, *et al.*, 1953; Gollop and Marshall, 1954). Aging of duck broods makes it possible to determine other valuable information. The waterfowl technician can back-date each aged brood and determine the approximate date of hatching, and the possibility of the brood having been observed during a previous census. Murdy (in Gollop and Marshall, 1954:14) devised a slide rule for the rapid back-dating of aged-brood data. This slide rule required the exchanging of center strips when shifting to a different species. The calculator described in this article resulted from efforts to devise a compact, single-unit calculator for the rapid handling of large series of aged-brood data.

Description of the Calculator

The calculator consists of a number of disks (one for each species) mounted on a circular calendar (Fig. 1). The circular calendar was constructed of lightweight cardboard, and the divisions for the dates were marked along the circumference with a pair of dividers. By using ⅛-inch divisions it was possible to have a calendar dating from May 15 through October 15. An individual disk for each species was cut from lightweight cardboard, and all of the disks and the calendar were fastened together by placing a Chicago screw through the

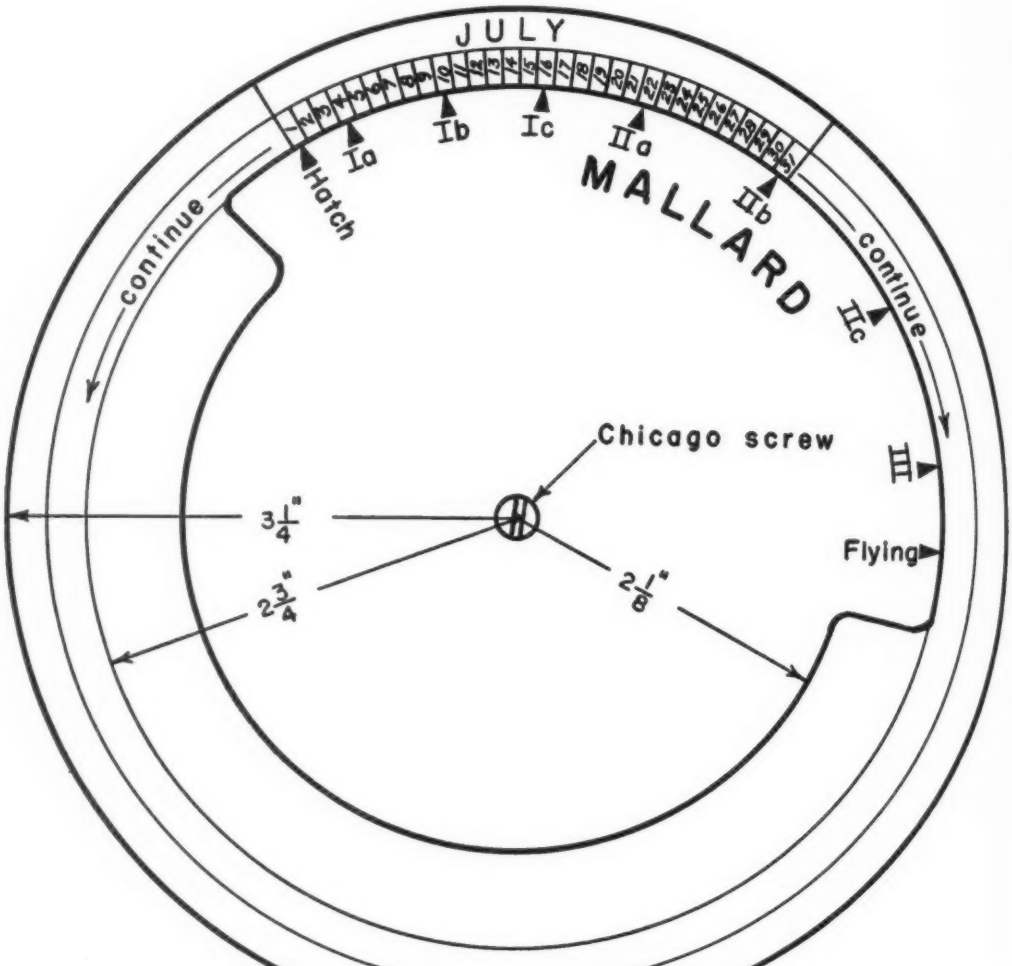

FIG. 1. Calculator for handling large series of aged-brood data.

center (the center hole can be punched or drilled). The plumage subclasses were marked on each disk by referring to the approximate midpoint age for the corresponding plumage subclasses for that species (Gollop and Marshall, 1954:9), and spacing them along the disk so that they were aligned with the appropriate dates on the calendar. Tabs may be attached to each disk to facilitate the selection of the proper disk during operation.

INSTRUCTIONS FOR USE

Select the disk for the species in question (rotating the other disks out of the way) and align the plumage subclass of the brood at time of observation and the date of observation on the calendar. Approximate dates of hatching, of each plumage subclass, and when the power of flight was attained can be read directly while the disk is in the above position.

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EFFECTIVENESS OF TWO FLUSHING DEVICES USED IN HAY MOWING[1]

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Biologists at the Rose Lake Wildlife Experiment Station tested two devices designed to reduce wildlife losses during hay mowing. We ran the tests on the farm area of the station near Lansing, Michigan, from 1950 through 1955. During four of these years we tested the "Ohio" flushing bar (Warvel, 1949) using four-pound cast-iron sash weights suspended from cables, and during three years we used the extension of the exhaust pipe of a tractor as a flushing device. Flexible metal tubing was attached to the exhaust pipe and supported by the bar used for the "Ohio" flushing device. This arrangement directed the noise and blast of the unmuffled exhaust into the hay about 13 feet in front of the cutter bar and in the middle of the swath. We found both devices to be mechanically satisfactory, requiring little maintenance.

Our tests had the advantage of being closely observed but the disadvantage of dealing with a small population of ring-necked pheasants. Game flushed or killed was tallied by a biologist riding on the mowing machine. We mounted a seat on the caster wheel of a John Deere No. 5 Power Mower so that the observer could get a clear view of the cutter bar and the effects of the flushing device. Because of low pheasant numbers, biologists had to observe the cutting of over 900 acres of hay in order to get approximately 100 pheasant flushes from both of the devices and the control. Spring pheasant numbers on the experiment station varied between six and eight birds per 100 acres during the study period, and hayfield losses were not a serious mortality factor. There was approximately one nest per 30 acres of hay during the 6-year period. While the low pheasant population was not ideal for the test, I feel we did flush enough pheasants to establish the relative effectiveness of the two devices under Rose Lake conditions. In the cutting of 936 acres of hay, 304 pheasant and 101 rabbit flushes were observed, and 13 adult hen and 47 juvenile pheasants and 15 rabbits were killed. We used a John Deere Model B tractor operating at between four and five miles per hour. The hay was second- and third-year alfalfa mixed with smooth brome grass (*Bromus inermis*). Figures given in this paper are for the first cutting only. The first cutting usually began at or just before the peak of pheasant hatching so that most of the fields were actually cut just after the hatching peak had passed. Between 15 and 20 individual hayfields were involved each year, and a total of 35 different fields were cut during the 6-year period. For the first three years we cut half the total hay acreage with the "Ohio" bar and half as a control. The fourth year we cut a third with the "Ohio" bar, a third with the exhaust, and a third as a control. For the last two years we cut half the acreage with the exhaust and half as a control. Each individual field was cut entirely by one method. We attempted to cut adjoining fields by different methods, and during the test period all fields were at some time cut by each method.

Our tests failed to show that either the "Ohio" bar or use of the exhaust blast reduced hayfield mortalities (Table 1). We were disappointed with the results, since investigators in other states have reported greatly reduced pheasant losses when using the Ohio–type flushing bar (Wisconsin–Bell, 1954; Iowa–Boehnke, 1954, and Klonglan, 1955; North Dakota–Fisher, 1954; Ohio–Warvel, 1949, and Swagler, 1951). The failure of the exhaust blast was not surprising, in view of the experimental findings of Stewart and Dustman (1955) regarding the response of incubating pheasants' auditory stimuli.

For every ten pheasants of all ages flushed from hayfields where the Ohio bar was used, 2.3 were

[1] A contribution of Federal Aid Project W-40-R. Data collected by staff of the Rose Lake Wildlife Experiment Station.

TABLE 1.—PHEASANT AND RABBIT MORTALITY FROM HAY MOWING, ROSE LAKE WILDLIFE EXPERIMENT STATION, 1950–55

Test	Years	Acres Cut	Pheasants							Rabbits		
			Flushed			Killed			Per 10 Flushed	Flushed	Killed	
			Hens	Juv.	Total	Hens	Juv.	Total			No.	Per 10 Flushed
Control (no flushing device)	1950–55	340	18	90	108	5	8	13	1.2	31	7	2.3
"Ohio" bar	1950–53	399	18	78	96	4	18	22	2.3	41	8	2.0
Exhaust blast	1953–55	197	15	85	100	4	21	25	2.5	29	0	0

killed, compared to 2.5 when the exhaust device was used. Only 1.2 pheasants were killed when no flushing device was used. We did not encounter enough adult hens during the test to establish differences between methods. A chi-square test did reveal a significant difference (.02 level) in the loss of chicks between the use of the flushing devices and the control, the use of each device resulting in a higher loss of chicks. It is possible that a larger sample of hens would reveal that they react in a different manner toward the noise and movement of the flushing devices. The chicks apparently tended to "freeze" in response to the extra disturbance of the Ohio bar and the exhaust blast.

The exhaust device appeared to be effective in lowering rabbit losses (Table 1); but the number of rabbits flushed was small, and the highly significant results obtained might be misleading.

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USE OF PROLACTIN TO INDUCE BROODINESS IN TWO WILD TURKEYS

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A restocking technique, described as the "adoption" method, has recently been given some consideration by several investigators. Stanford (1952), in Missouri, reported on the results of an adoption experiment in which adult bob-white quail (*Colinus virginianus*) were released with 9- to 16-day-old "foster" chicks. A related study, reported by Crispens (1956) in Ohio, concerned an evaluation of the adoption method when prolactin was used to induce broodiness in female ring-necked pheasants (*Phasianus colchicus*) before their release with adopted chicks. In connection with this latter study, I wish to report some preliminary investigations that were conducted to test the use of prolactin to induce broodiness in the wild turkey (*Meleagris gallopavo*).

Two adult female wild turkeys were obtained from the Waterloo Experiment Station, Ohio, and each housed in a separate pen 36 inches by 30 inches by 36 inches in the Ohio State University ornithology laboratory. The sides and floors of the pens were constructed of ½-inch mesh wire and the tops covered with burlap. Burlap was also placed between the pens to reduce excitement or stimulation of the birds by visual means.

In March, 1954, each wild turkey received an injection of 18 mg. of prolactin per day for six days. After one injection they became quieter; after three injections they were beginning to cluck. At the end of the injection period, three 2-week-old, culled, domestic turkey poults were placed with each hen; within 12 hours the hens were brooding the chicks. After four days, although brooded and cared for by the hens, the six chicks were dead. Their deaths were attributed to an inability of these already-crippled poults to adjust to the wire floors of the pens.

Two days later a group of 2-week-old white leghorn chicks were obtained for use in other studies. Since one of the principal objectives of this work with the wild turkey hens had been to determine if they would remain broody for an extended length of time after the injection period, it was decided to place three of the white leghorn chicks with each bird. Both hens were brooding the chicks within 79 hours after the chicks were placed in the pens. They continued to brood them for a period of three weeks, when it became necessary to discontinue the study.

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[2] This paper is part of a thesis presented in partial fulfillment of the requirements for the degree of Master of Science. The study was made possible by a Wildlife Research Fellowship granted through the Ohio Cooperative Wildlife Research Unit: Ohio State University, Ohio Division of Wildlife, the U.S. Fish and Wildlife Service, and the Wildlife Management Institute cooperating. The author is grateful to E. H. Dustman, Leader, Ohio Cooperative Wildlife Research Unit, under whose direction this study was made.

THE PROBLEM OF CHANGING BELIEFS AND ATTITUDES

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The statement that 90 per cent of wildlife management is management of people has been repeated at most wildlife conferences in recent years. Few administrators in the wildlife field are likely to quarrel with this generalization, because the application of the results of excellent research findings has so often been frustrated by opposition from the public. To combat this, most game departments now have conservation-education or public-relations sections; but the problem of effecting change remains acute, and some game departments are still burdened with bounties, buck laws, and other relics of the past.

In that field of education bringing basic understanding to the public, Gabrielson (1951) summed up the situation well when he wrote, "This field has been most intensively worked and has on the whole yielded meager results when compared to the effort exerted."

I wish to discuss the problem with special reference to deer management, but it will be obvious that the diagnosis of this problem has wider application.

The deer-management pattern in many provinces and states has been remarkably similar. In the last 10 to 20 years administrators have been faced with deer herds consuming food faster than it is being produced. Forest damage, unthrifty deer populations, and periodic die-offs have frequently been described. An often-suggested remedy for this situation is to kill more deer, but when attempts have been made to change regulations to permit a larger harvest during hunting seasons, resistance, often violent and emotional, has sprung up from deer hunters and other groups.

Large quantities of written material have been distributed and uncounted talks have been delivered to sportsmen's clubs in attempts to bring hunter beliefs closer to reality. There has probably been no inadequacy in the technical quality of much of the material presented, and I should like to suggest that the disappointing results are due to a lack of understanding of the psychological barriers that exist, to the structure of society, and to the manner in which opinions are formed, held, and changed.

The deer manager is not faced with a problem of simple education, i.e., of placing information and understanding on an issue in the minds of the public about which no prior knowledge or opinion exists. His problem is more complicated and involves the changing of existing beliefs and attitudes, some of which may be strongly held by segments of his target group. Hyman and Sheatsley (1952) have pointed out some of the problems of effectively reaching target groups with written material. They found that, in addition to a hard core of chronic "know nothings" who are very hard to reach no matter what the level or nature of the information, people tend to expose themselves to information that is congenial with their prior attitudes, and to avoid exposure to material that is not congenial. A person's perception and memory of materials shown to him are also often distorted by his wishes, motives, and attitudes. These behavior characteristics tend to deter any change in beliefs or conduct unless motivation on an issue happens to be low.

However, Hyman and Sheatsley (*ibid.*) do not discuss the pressure that society brings to bear upon an individual in forming or changing his beliefs. To understand this it is necessary to consider the structure of society.

Krech and Crutchfield (1948) have described society as "an interrelated system of social groups." They define a group as ". . . two or more people who bear an explicit psychological relationship to one another. . . . Such social groups influence the needs, beliefs, attitudes, and actions of the people involved, and the structure and function of such groups are in turn determined by the dynamic interactions of their constituent members. For most groups it can be safely generalized that group membership serves a function for the individual. Through it he satisfies needs and demands."

A normal individual, then, is not a free agent in making up his mind on an issue. Lewin (1952) wrote that: "Many social habits are anchored in the relation between the individuals and certain group standards. If an individual should try to diverge too much from group standards, he would be ridiculed, treated severely, and finally ousted from the group. Most individuals therefore stay pretty close to the standard of the group to which they belong or wish to belong. In other words, the group level itself acquires value. It becomes a positive force keeping the individual in line with the standards of the group."

It thus becomes apparent that any attempt to change the opinion of individuals separated from their group is not likely to be successful. Brown (1954) has pointed out that "the group must be dealt with as a whole. The obvious reason for this is that since the attitudes are a function of the group and its situation, it is useless to attack them in the individual member. Attempting to change a person's views into views which conflict strongly

[1] The writer wishes to acknowledge the assistance of Professor J. D. Ketchum of the Department of Psychology, University of Toronto, who suggested reading material, and of C. D. Fowle, who made useful criticisms of the manuscript.

with those of his group is, in effect, asking him to set himself against the group, and since to most people the respect of their group is more important than holding of an opinion, we are not likely to be successful in most cases."

The field staffs of most game departments are constantly meeting groups with whom they must work, but they usually do so under circumstances unsuitable for effecting change. An invitation to speak at a dinner or annual meeting of a club provides an opportunity to explain policies and programs. If a hard-hitting, aggressive approach is adopted when the issue under discussion is highly controversial, more harm than good may result, for ". . . lecturing at people is, in a sense, a form of verbal attack which many people inwardly resent, and, in trying to change a man's views we are attacking something that is part of himself, we are asserting that he is wrong and we are right. Reason, however important a part it may play in society, does not play a major part in most people's lives. Lecturing, logical argument, and the individual approach are, therefore, unlikely to lead to success in changing group attitudes, and the most successful method of doing this has been shown to be the use of group discussion" (Brown, *op. cit.*).

This technique for changing opinion and conduct was studied by Lewin (*op. cit.*), who carried out a series of experiments in which he measured its effectiveness compared with lecturing to groups and with individual instruction. In each case he found that a group discussion followed by a decision was more successful in effecting change.

In using this technique the size of the group is important. There is a tendency for too large a group to lose cohesion and split into units that may ramble away from the issues in question while the discussion leader is unable to function with more than one unit.

Perhaps six or seven individuals should be the optimum. If group discussion with the object of arriving at a decision is to be held with a sportsman's club numbering 20 or more people, it may be necessary to split the meeting deliberately into manageable units, making sure that a qualified discussion leader is present in each. Before each unit begins its discussions, the problem can be outlined to the meeting as a whole, and at the end a spokesman from each can outline conclusions.

The layout of a meeting hall may affect the tone of the discussion. Head tables, platforms, or chairs set apart for speakers foster a feeling in the audience of *we* and *they*. The discussion leader is more apt to be successful if he is accepted as one of *us*. He may help to create this feeling if he deliberately chooses a seat at one side of the table or in the middle of the group, avoids all the trappings of authority, and does not wear a departmental uniform.

His function in the group is to outline the problem, ask for help in finding a solution, encourage all members of the group to speak freely, answer questions, and unobtrusively feed factual information into the discussion. He should talk as little as possible beyond fulfilling these obligations.

Lewin (*ibid.*) has pointed out that the group-decision procedure which he used in his experiments ". . . attempts to avoid high pressure methods and is sensitive to resistance to change. Its success may be due in part to the attempt to bring about a favourable decision by removing counterforces within the individuals rather than by applying outside pressure." High-pressure lecturing methods, if they are successful at all, are apt to be accompanied by a state of relatively high tension which ". . . above a certain degree is likely to be paralleled by higher aggressiveness, higher emotionality, and lower constructiveness." These qualities are sometimes all too apparent in some groups, and the abuse to which some wildlife technicians have been subjected may well be traced to their own misguided efforts.

Social support for established beliefs and attitudes acts as an obstacle in the conversion of individuals to fresh views. This trait should not be overlooked by the wildlife manager in planning his program, for it can be used to assist him. Krech and Crutchfield (*op. cit.*) have pointed out that our culture is fortunately not homogeneous. In taking measures to change beliefs and attitudes, we should seek out and use suitable groups already subscribing to the views we wish to promote, and with whom our subjects would be happy to identify themselves. When no proper group exists for such identification, it becomes difficult if not impossible to establish certain beliefs and attitudes. We must attempt to educate the individual as a part of a group, and we can do that by taking advantage of the diversification within our cultural pattern.

In solving many of the acute public-relations problems that beset the natural-resource manager, the best efforts of the press agents and advertising experts who often staff education and information sections have been notably unrewarding. Unquestionably there is a great need for research carried out by men trained in the appropriate field. In partnership with social psychologists, wildlife managers should study people as assiduously as they study deer, pheasants, or smallmouth bass. Until such study is placed on an adequate scientific basis, progress in wildlife management is likely to remain slow and uncertain.

SUMMARY

Opinions remote from reality held by sportsmen and other groups have prevented game departments from adopting sound deer management programs. Written material used in information campaigns is not effective in changing strongly held beliefs. Group discussions are more effective than lectures or individual instruction because opinions are a function of the group and its situation. The social

support of groups subscribing to progressive views should be used to make converts.

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THE USE OF DEWATERED LAND IN SOUTHEASTERN WATERFOWL MANAGEMENT

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The steady advance of civilization has reduced southeastern waterfowl habitat and intensified the problem of furnishing sufficient food for the wintering concentration of these birds. To meet this problem, game managers are making increased use of dewatered land. Dewatered land may be defined as land flooded during the cool-weather period but drained during all or part of the plant-growing season. To be of value to waterfowl management, the drained period must be long enough for natural vegetation or planted crops to mature seed.

Dewatering may be either partial or complete, natural or artificial. Naturally dewatered areas may include bottom-land lakes with river outlets drained by low-river levels in summer and refilled by rises in late fall and winter. In this category, too, would come bottom-land fields covered by frequent overflows in fall and winter, and field basins dry in summer but refilled with the beginning of fall rains.

More important, and involving a considerable acreage, are areas dewatered artificially. The old rice plantations of the South Carolina and Georgia coast were excellent examples, and there remains a substantial acreage along both the Atlantic and Gulf coasts that is dewatered through tidal action or by pumping. Many private individuals and hunting clubs throughout the Southeast are using this form of management, creating small impoundments by placing earthen dams fitted with control structures across natural drains and small streams, allowing these to fill during fall and winter, and draining them through gravity flow each spring.

Along the Tennessee River valley of Alabama and Tennessee, the Tennessee Valley Authority has diked large areas of shallow backwater, and these are pumped dry as a malaria-control measure. Pumping starts with the beginning of the mosquito breeding season in May and continues through mid-September. After the termination of pumping, stream and spring flow and fall rains gradually refill these units. The authors are familiar with at least two state-managed public hunting areas where state funds are used for dewatering through pumping; numerous clubs and individuals also rely on pumping, both for drainage and refilling.

Material presented in this paper has come from experience gained in the handling of dewatered areas on the U.S. Fish and Wildlife Service's Wheeler National Wildlife Refuge in Alabama, the Savannah National Wildlife Refuge in Georgia, and the Tennessee National Wildlife Refuge in Tennessee, from state-managed public hunting areas in Alabama and Tennessee, and from club and privately owned land throughout the Southeast.

Thanks are due to J. L. Hetlin, in charge of public waterfowl hunting areas in Alabama, to Parker B. Smith, in charge of similar areas in Tennessee, and to V. L. Childs and Eugene Cypert, of the Tennessee National Wildlife Refuge, for reviewing and commenting on this paper. This article is advanced as a practical guide to the management of dewatered areas in the southeastern United States, based on current knowledge, and is not intended to cover all local environmental factors encountered in the handling of such areas.

GREEN-TIMBER RESERVOIRS

Green-timber reservoirs involve a specialized form of dewatered land management. Low dikes are used to impound water shallowly over flat bottom lands grown to hardwood timber. While the period of permissible flooding may vary with latitude and timber type, it should be withheld until the first killing frost, and dewatering should be complete by mid-February. The oak mast and other foods made available are particularly attractive to mallards (*Anas platyrhynchos*) and wood ducks (*Aix sponsa*), two of the most important species

from a practical management standpoint. Such reservoirs will be given limited use by other duck species, but are unlikely to attract Canada geese (*Branta canadensis*). Projects of this type are feasible only where the gradient will permit the flooding of a substantial acreage with low dikes and inexpensive water-control structures. Water oak (*Quercus nigra*) and willow oak (*Q. phellos*), commonly called "pin oaks" in the South, are the most desirable species for this type of flooding.

Once initial development is completed, annual maintenance costs are low. The cost of food production is insignificant, and the only management required is timber-stand improvement to favor mast-producing trees. Such projects are limited by the presence of suitable areas, and by the comparatively short period when food can be made available.

Open Dewatered Areas

The management of open dewatered land for waterfowl has several advantages over the similar management of uplands. Soils are usually, although not always, alluvial and fertile, and the water table is near the surface, reducing but not eliminating drought damage. Since the crops produced are flooded, they are available to more species of waterfowl rather than to only the geese and the field-feeding species of ducks. Depredation from crows or trespassing livestock is reduced or eliminated, and there is no conflict with present antibaiting regulations. Compared with permanent-level pools, dewatered units undoubtedly produce a greater poundage of dry food per acre, and pest-plant intrusion is more easily controlled.

These advantages are at least partially offset by a number of disadvantages. Canada geese may make only limited use of dewatered areas. Crops are subject to damage from heavy rainfall or to complete loss from cloudbursts and pump and structure failure. Permanent pastures and all winter crops are either impractical or impossible. Since land of this type is seldom dry enough for use before late spring or early summer, crops are usually limited to those that have moderate or short growing seasons.

Since risk is high, the possibilities of reducing the cost of operation through share rentals to local farmers are limited or lacking. Plant studies on dewatered land show that wild millet (*Echinochloa crusgalli*), smartweeds (*Polygonum* spp.), beggarticks (*Bidens* spp.), sedges (*Cyperus* spp.), large-seed panic grasses (*Panicum* spp.), and sideseed grasses (*Paspalum* spp.) are common the first year of dewatering and provide a quantity of natural waterfowl foods. By the second year of dewatering, woody reversion has begun. Herbaceous pest plants have intruded, and 75 per cent of the waterfowl food has been lost. By the third year, reversion has progressed to such a degree that 90 per cent of the desirable waterfowl food plants have been crowded out. Under the conditions of moist, fertile soil, warm weather, and long growing seasons, reversion is extremely rapid.

Management of this land through natural food plants is economical and desirable. Fair results may sometimes be obtained through the manipulation of water levels, coupled with rotation disking. However, disking on a rotation longer than three years is impractical. Fair results are sometimes obtained by broadcasting millet, preferably by airplane, on unprepared land. This may be done by sowing damp seed in shallow water, just prior to drainage, or by sowing dry seed on wet flats, immediately after dewatering. Later, seed may be sown on dry flats after these have checked and cracked, when enough seed will lodge in cracks to provide a stand. These methods are risky; and success depends, to a considerable extent, on good rainfall soon after planting. While expensive, the annual disking or plowing of slough beds and planting these to agricultural crops is the most dependable method of producing large quantities of preferred waterfowl food.

Crops for Dewatered Areas

At the beginning of management, dewatered areas may be studded with stumps and overgrown with brush and vines. Special equipment may be needed to reclaim them. Bulldozers are useful for uprooting stumps and heavy brush. Small brush may be controlled with rotary-type mowers, heavy offset disks or heavy bush-and-bog disks. Once land has been cleared and given an initial disking with heavy harrows, conventional farm machinery, including wheel tractors, disk harrows, and seeders can take over maintenance. Light crawler tractors or wheel tractors with oversize tires may be needed for wet areas. Grain drills are useful tools on clean land, but on rough new ground the spreader-type seeders are more satisfactory.

The management of dewatered land should usually supplement rather than supplant upland management. Where both dewatered land and upland fields are available, the cost of management may be reduced by exchanging upland rental for plantings made in the dewatered area. Where this is not the case, it may be possible to share-rent the higher elevations of the dewatered area and exchange the rental for broadcast plantings at lower elevations. Neither pasture nor hay crops are desirable, since winter flooding prohibits the use of perennials that would be of value for goose forage, and annuals would have nothing to offer waterfowl. Careful consideration should be given to the length of growing seasons of crops used, and a planting schedule should be set up and strictly followed to insure that all crops mature before frost.

The higher land may be row-cropped to corn, the grain sorghums, soybeans, and in sandy locations, to peanuts. Varieties with short growing seasons should be used. Corn, due to its high waterfowl preference and slow rate of consumption,

should be favored, although its use will be limited to the highest elevations. Lower elevations are limited to crops having moderate or short growing seasons and capable of producing in broadcast stands. In planting these broadcast crops, it has usually been found best to begin work as soon as the soil will support machinery. Delay may allow vegetation to become so rank that it is difficult to cover by disking. However, where soil is lacking in organic matter, it may be desirable to wait for this vegetation to reach a height of several inches, then plow or disk it under for soil improvement. Land should be disked to a suitable seed bed and seed planted with a grain drill or by a spreader-type seeder followed by a disk harrow set at a sufficiently slight angle as only to cover the seed. Heavy seeding should be employed to compete with cocklebur (*Xanthium strumarium*) and other pest vegetation. Where dewatered units are sufficiently isolated that the use of herbicides does not pose a danger to cultivated crops, consideration should be given to this method of pest plant control. Dewatered soils are often fertile and contain a high proportion of organic matter. However, as is generally true with all agricultural operations, soil tests to determine deficiencies and the proper use of fertilizers will pay dividends. Where crops will be flooded reasonably early, it is not necessary to level or otherwise manipulate them, as is often required on uplands, to insure good waterfowl use. However, it may be desirable to level those crops on the higher elevations, where flooding seldom takes place until late winter; care must be taken here, however, not to conflict with antibaiting laws.

Crops that have proved most satisfactory for these broadcast plantings are the grain sorghums, soybeans, millets, and buckwheat. Grain sorghums have the advantage of a comparatively short growing season and heavy production of high-quality waterfowl food from broadcast stands. They have the disadvantages of light waterfowl use unless flooded or leveled, frequent damage by midges and the green corn worm, mold damage in wet weather, and heavy depredation by blackbirds.

The soybeans produce well on lowland, and the number of varieties with varying lengths of growing seasons allow planting over a considerable period. Large-seeded oil varieties have generally proved best. Rice is a highly preferred waterfowl food offering possibilities for use in dewatered units, although it requires specialized techniques of planting and is highly sensitive to soil and water conditions. It cannot be used where mosquito control is a primary function. Like grain sorghum, it is subject to heavy damage by small birds. Where soils are especially sandy and the dewatering season long, chufas are a possible crop, although a poor competitor.

Of the millets, Japanese and brown-top have usually proved to be most satisfactory under southeastern conditions, although pearl, German, Hungarian, and proso have given good results. Proso millet, especially the Early Fortune variety, has the shortest growing season of all summer annuals except buckwheat. The limber stalks of most of the millet group prevent damage by perching birds, and their tendency to fall makes leveling unnecessary. They are usually less subject to insect, disease, and mold damage than are the sorghums. Buckwheat produces fairly well during wet falls and owes its chief value to its extremely short growing season, which allows for late planting.

With all millets and buckwheat, too-early planting must be avoided, since seed may mature, shatter, and sprout before waterfowl arrive. Planting should be timed so that seed will mature just prior to frost. The use of a variety of different crops not only seems to be more attractive to waterfowl, but increases the chances of successful food production. Food preferences, often pronounced on uplands, seem less important when crops are flooded. As an example, soybeans may be given low preference on upland fields, but may be readily eaten when shallowly flooded in a dewatered area. Where water-level manipulation is possible, at least a portion of the crops should be flooded by the time the first heavy flights of waterfowl arrive. The level should be gradually raised and should reach the full mark by the end of the waterfowl hunting season on shooting areas, or by late January on sanctuaries.

It should be noted that the use of dewatered areas for waterfowl management is comparatively new, at least in the Southeast, and that improved techniques are certain to develop rapidly as more experience is gained. This paper has given a general summary of the methods used in various parts of the region. Modifications will be necessary to fit local soil, weather, and water conditions.

SUMMARY

The use of dewatered land is assuming increasing importance in the production of waterfowl food. Where suitable areas are available, green-timber reservoirs provide a cheap and easy means of attracting waterfowl, particularly mallards and wood ducks. The use of open dewatered areas is more involved. Proper management usually requires the clearing of stumps, brush and vines, and other preparatory work. The production of natural waterfowl food through water manipulation and rotation disking is sometimes possible, as is food production by sowing unprepared flats to millet or other crops, but these methods are not dependable. Actual farming, though more expensive, remains the most reliable method of producing large quantities of preferred food. This is best accomplished by row-cropping the higher elevations to corn, grain sorghums, and soybeans, and by broadcast planting the lower elevations to the grain sorghums, soybeans, millets, and buckwheat.

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EFFECTS OF PREDATOR GUARDS ON WOOD DUCK BOX USAGE[1]

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Since 1950, Rhode Island has had an active wood duck (*Aix sponsa*) nesting-box program. At first, little predation by raccoons (*Procyon lotor*) was experienced, but by 1953 it was realized that some type of predator guard for the boxes would be needed if the program was to continue. The type of guard selected was the wooden-tunnel type described by McLaughlin and Grice (1952). During the first year, guards measuring 3 by 4 inches and 4 by 4 inches were used; but by 1954, only the 4- by 4-inch guards were in use. At the conclusion of the 1954 nesting season, there was some feeling that the predator guards were greatly affecting usage of the wood duck boxes. In an effort to determine what effects the predator guards did have on the usage of wood duck boxes, a number of experimental areas were established in northern Rhode Island during 1955 and 1956 with boxes that had 4- by 4-inch guards.

Areas were selected that had good records for past usage of nesting boxes. Approximately 25 per cent of the areas had predator guards on all of the boxes, 25 per cent of the areas had boxes without guards, and 50 per cent of the areas had an equal number of boxes with and without guards.

During 1955 all of the boxes were checked three times between the middle of May and the latter part of June. In 1956 all of the boxes were checked during the middle of June, while some were also checked on the first of May and at the end of June.

Prior to the nesting season, all boxes were checked for usability, cleaned of all debris, and given sawdust where needed.

Boxes were considered to have been used if eggs were present, even though the hen may have deserted.

In 1955, 102 boxes on 20 areas were under observation and in 1956, 85 boxes were observed on 16 areas.

In localities where one-half of the boxes had predator guards and one-half of the boxes did not, the guards were reversed in 1956 from their 1955 positions, so that individual site preference would not be a factor in determining usage.

The usage of the boxes at the various sites is given in Table 1; it appears that, in general, the boxes without guards are preferred to the boxes with guards.

Chi-square tests were applied to the data using the null hypothesis that usage of the boxes with guards was normal. Results of the tests indicate that in 1955, when all areas are considered, the ducks showed a strong preference for the boxes without guards. An even greater preference is indicated on the areas where the hen had a choice in 1955. However, on areas that had guards on all boxes or lacked guards on all boxes, it appears that there was no significant difference between the number of boxes used on these areas in 1955. The results from 1956 present a somewhat different picture. The tests again indicate no significant difference in usage in the all or none areas, but they also show no significant difference when the tests are applied to all of the areas. As in 1955, there appeared to be a significant choice of boxes without guards on areas where the ducks had a choice, even though the boxes with guards in 1956 were the ones that were without guards in 1955. The difference between the results of the chi-square tests applied to all areas in 1956 as compared to 1955 is apparently due to the increased usage on all areas in 1956, particularly the locations that had guards on all the boxes. The usage on all areas was up from 53 per cent in 1955 to 72 per cent in 1956, and usage on the areas that had all guards went from 36 per cent in 1955 to 67 per cent in 1956.

TABLE 1.—USAGE OF EXPERIMENTAL BOXES, 1955-56

Type of Box Available	Percentage Occupied (Number of Boxes in Brackets) 1955	1956
Areas where half the boxes had guards and half had none		
Boxes with guards	46 (24)	69 (16)
Boxes without guards	88 (24)	100 (16)
Areas where all boxes were the same		
Boxes with guards	36 (28)	67 (27)
Boxes without guards	50 (26)	62 (26)

In summation, the data seem to indicate that, when hen wood ducks have a choice, they prefer to nest in boxes without guards. However, when all the boxes in a given area have guards or when nesting pressure is high, the predator guards used in this project did not appear to affect the usage of wood duck boxes.

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LEUCOCYTOZOON BONASAE CLARKE IN MICHIGAN SHARP-TAILED GROUSE

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Leucocytozoon bonasae was first described from ruffed grouse (*Bonasa umbellus*) by Clarke in 1935. That same year Saunders (1935) reported the presence of *Leucocytozoon* in sharp-tailed grouse (*Pedioecetes phasianellus campestris*) in Michigan. Since O'Roke (1934) clearly demonstrated that *L. simondi* could be an important factor in the mortality of ducklings, researchers studying grouse have sought to determine whether *L. bonasae* may play a similar role in the grouse as a group, particularly with respect to periodic population declines.

The majority of the data for this report were collected during the winter and early spring months of 1952 and 1953 as part of an ecological study of sharp-tailed grouse in the Upper Peninsula of Michigan (Peterle, 1954).[1] Therefore, the data were derived only from potential breeding populations.

Blood smears were obtained from 126 wild-trapped birds, stained with Geimsa's stain, and carefully examined for the presence of blood parasites. At the time of examination, each positive smear was assigned a number to indicate the relative intensity of infection. A rating of *1* indicated that a long search was necessary to locate a parasite; a 2 rating meant enough parasites for rather prompt determination; and a 3 rating was used when a parasite occurred in nearly every field at a magnification of ×100.

Gametocytes of *L. bonasae* were found in varying intensities in 105 of 157 smears examined. Table 1 shows the number of slides examined, the percentage infected, and the average intensity of infection by sex and age classes. The figures indicate that in the study area adult sharp-tails were more frequently infected than juveniles, 72 per cent and 56 per cent, respectively. However, this difference was probably much more apparent than real.

When the data were grouped according to the date on which smears were obtained (Table 2), it was found that 145 of them were taken during the months of December through May. Slightly more than half of these were taken during the months of April and May when the males were on the dancing grounds and were more easily captured by use of a cannon-net trap. Probably the most significant finding of the study was that only 31 per cent of the blood smears obtained from December through March were positive for *L. bonasae* as compared to 95 per cent of those taken in April and May. The intensity of infections was also much higher in April and May than in earlier months (Fig. 1). However, trapping data showed that the populations being sampled were identical throughout the trapping season (Peterle, *ibid.*).

A further analysis was made of 57 smears obtained from 26 retrapped birds; the time lapse between smears varied from 6 days to 1½ years. All

TABLE 1. — INCIDENCE AND INTENSITY OF LEUCOCYTOZOON GAMETOCYTES IN MICHIGAN SHARP-TAILED GROUSE 1951–54

Sex and Age Group	No. of Smears Examined	Per Cent Infected	Average Intensity of Infection[1]
Adult M	95	72	1.9
Adult F	10	80	1.4
Immature M	45	56	1.5
Immature F	7	57	2.2
Adult	105	72	1.9
Immature	52	56	1.6
Male	140	66	1.8
Female	17	71	1.4
Total	157[2]	67	1.8

[1] Coded index of relative intensity; explained in the text.
[2] All smears included; the number of birds was 126.

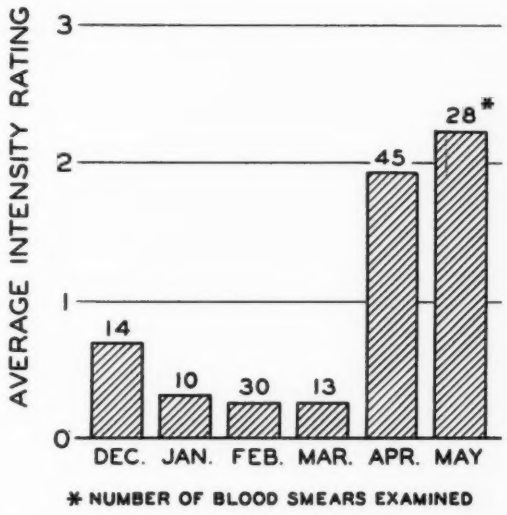

FIG. 1. Intensity of infection of *Leucocytozoon* in sharp-tailed grouse, Upper Peninsula, Michigan, 1951–53.

[1] Pittman-Robertson Project W-70-R, Michigan.

TABLE 2. — MONTHLY DISTRIBUTION OF BLOOD SMEARS AND PERCENTAGE OF INFECTION WITH *Leucocytozoon bonasae*[1]

Year	December		January		February		March		April		May	
	No.	Per Cent Infected	No.	Per Cent Infected	No.	Per Cent Infected	No.	Per Cent Infected	No.	Per Cent Infected	No.	Per Cent Infected
1952	14	57	4	0	18	22	4	25	13	100	5	100
1953	—	—	6	50	12	25	9	22	32	91	23	100
1954	—	—	—	—	—	—	—	—	—	—	5	80
Total	14	57	10	33	30	23	13	23	45	93	33	97

[1] Grand Total: 145 smears; 95 infected, or 66 per cent. The 12 smears obtained during other months of the year were too scattered to consider.

the birds of this group that were captured in April and May were infected. Positive smears were obtained, at one time or another, from all but 4 of the 26 birds, for a total infection from all smears of 65 per cent.

DISCUSSION

To interpret the meaning of the data, it is necessary to know something of the nature of the various types of blood infections that may be encountered in studying leucocytozoa. After being bitten for the first time by infective vectors, a susceptible host may have a relatively high percentage of its blood cells parasitized. This is called the "primary parasitemia." If the host survives the initial attack, it may occasionally make a complete recovery. However, infection most often persists in a chronic or latent state, which begins in early fall with the disappearance of vectors and continues through the winter. Chronic infections are characterized by infrequent appearance of parasites in the peripheral circulation and may or may not be detected if only one smear is taken. These are the types of infection one must expect during hunting and winter trapping seasons. In *L. simondi* infections in ducks, Chernin (1952) has shown that with the onset of the breeding season something, probably a physiological change in the bird, triggers a relapse and parasites become common in the circulating blood cells, although not as numerous as during the primary infection. This is well demonstrated by our observations on sharp-tailed grouse captured during April and May. None of the infections observed was heavy enough to be considered a primary attack.

Inasmuch as the specimens for this study were taken at times when only light infections might be expected, the greatest significance of the findings must be placed upon occurrence, rather than intensity, of infections. Furthermore, the most significant data on occurrence were those obtained during the breeding period when infections had passed from a latent state into relapse and when parasites could be expected to be present in the blood at all times and in greater numbers.

Of 78 birds trapped during the breeding season, 95 per cent were infected. It is very likely that this represents the occurrence of infection that existed throughout the fall and winter, since the samples were taken before natural transmission could occur. Thus it becomes apparent that hunting-season or winter surveys of the occurrence of *L. bonasae* in grouse populations might demonstrate as few as one-third of the cases actually present, unless at least three blood smears per bird could be obtained over a period of time.

The most malignant factor presented by the high percentage of infection in the breeding population is the great opportunity for vectors to obtain infective blood meals and transmit infections to susceptible chicks upon subsequent feedings. Extensive mortality of grouse chicks from *L. bonasae* infections has not been definitely reported. There has been, however, considerable speculation, pro and con, as to the role such infections may play in causing periodic population declines.

Leucocytozoon simondi and *L. smithi* have been shown to be serious pathogens of young ducks and turkeys, respectively (O'Roke, *ibid*; Biester and Schwarte, 1948); and there is still no evidence that *L. bonasae* is not a factor to be reckoned with in accounting for juvenile grouse mortality. It appears that the potential must be considered very high, especially when the breeding population, as sampled by this Michigan study, is almost completely infected.

From the standpoint of rounding out the data reported herein, it is unfortunate that brood information and collections of chicks were very limited. The chicks compose the age class most likely to be affected, and their survival must be the object of definitive studies if the effects of *L. bonasae* infections are to be evaluated. For, even though this potential pathogen has not been definitely associated with periodic population declines, the annual losses that it may cause, directly or indirectly, may be even more serious than the more spectacular periodic reductions.

SUMMARY

One-hundred and fifty-seven blood smears were obtained from 126 sharp-tailed grouse (*Pedioecetes phasianellus campestris*) trapped in the Upper

Peninsula of Michigan during the winter and early spring months of 1951 to 1954. *Leucocytozoon bonasae* was found in 67 per cent of these smears. However, it was found that only 31 per cent of the smears taken from December through March were positive, as compared to 95 per cent of those taken in April and May. The intensity of infection was also markedly higher in the latter sample. The occurrence of infection in 95 per cent of the smears made from spring-trapped birds, which composed approximately 50 per cent of the total sample, was considered to be representative of the incidence of infection for the entire population sampled. Thus, late fall and winter surveys may disclose as low as one-third the actual occurrence of infection. Since a high rate of infection was found in the potential breeding population studied, it seems important that the effects of *L. bonasae* on chicks be thoroughly investigated.

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SOME EFFECTS OF A SEVERE WINDSTORM ON COOT NESTS[1]

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While the damage by winds of high velocities to man-made structures can be readily measured, the effects of such storms on wildlife usually are subject only to subjective estimations. A windstorm of hurricane proportions, which occurred on June 7, 1954 at Mud Lake National Wildlife Refuge in northwestern Minnesota, afforded an unusual opportunity to measure some of its effects on a nesting coot (*Fulica americana*) population and to judge the relative protective values of three different types of cover.

The storm.—Southeast winds of velocities estimated at 30 miles per hour prevailed at the refuge all day on June 6. The wind increased during the morning of June 7 to an estimated 40–60 miles per hour by noon and reached a peak of approximately 90 miles per hour between three and five in the afternoon. The general direction was from the south-southeast, due south, and south-southwest. The Weather Bureau Summary of June 1954 (Climatological Data—Minnesota, Vol. XL, No. 6) states: "One of the most severe windstorms on record occurred on the 7th in western and central Minnesota." At the refuge, a steady southwest wind of approximately 30–35 miles per hour prevailed on June 8, and this had shifted to a wind of 10–15 miles per hour by the morning of June 9.

In the general area, heavy damage to buildings, and telephone and electrical power lines occurred. At the refuge, hundreds of trees, chiefly aspen (*Populus balsamifera* and *P. tremuloides*), were either uprooted or snapped off by the winds. All east-west dikes were battered by wave action and most adjacent areas were soaked by rain and spray from the pools. Stands of emergent vegetation on the windward sides of open water areas were flattened. Debris was stranded up to 3 feet above normal water levels and as much as 25–30 yards back from the normal shorelines of some islands that bordered especially large areas of open water.

The nests.—The summer of 1954 was a season of high coot nesting populations at the refuge. Nesting activity reached a peak in early June, and nearly all coot pairs were incubating at the time when the storm occurred.

Forty-six coot nests were found in Mud River Pool through June 16 (Fig. 1). With respect to the windstorm, these are divisible into four major groups: (1) eleven previously located nests that were destroyed by the storm; (2) nineteen previously located nests that survived the storm; (3) ten nests located after the storm that obviously had been present at the time of the storm as determined by their stage of development—in all cases with pipped eggs less than eight days following the storm; (4) six nests located subsequent to the storm that apparently were started after that date as determined from the number of eggs (less than five) and from the nest construction.

Of the 11 nests that were destroyed during the storm, eight vanished along with their marker stakes and vegetative cover. Two of the other three remained as battered and waterlogged platforms

[1] Paper No. 3754 Scientific Journal Series, Minnesota Agricultural Experiment Station, St. Paul 1, Minnesota.

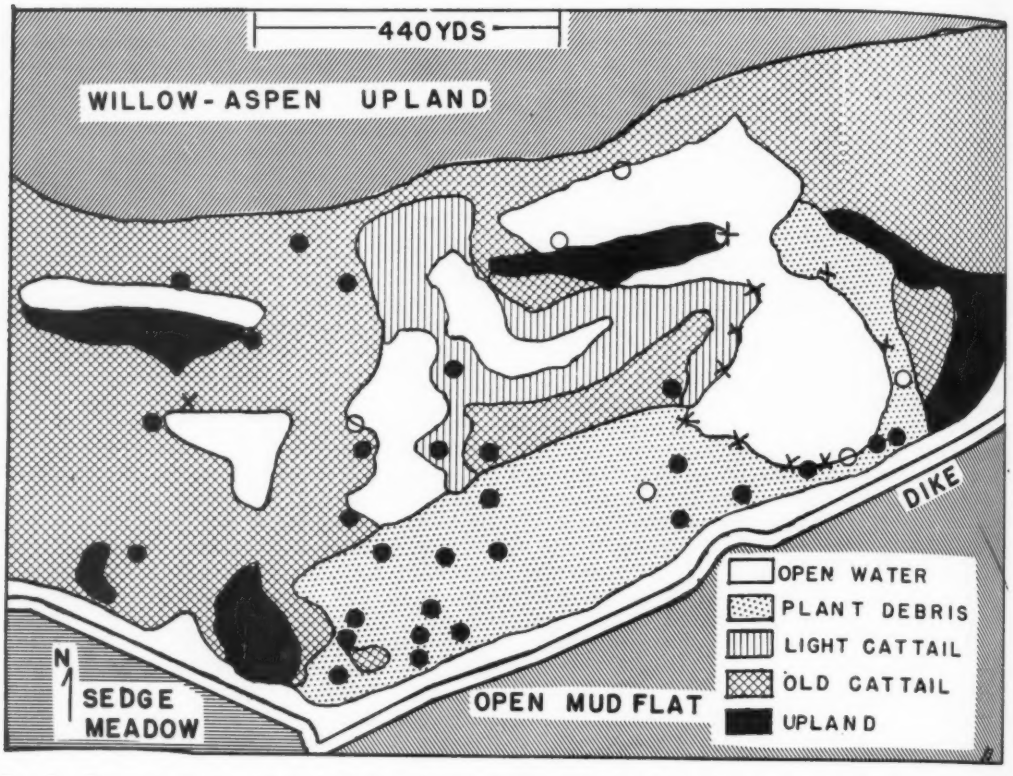

FIG. 1. Diagrammatic map of Mud River Pool cover types showing location of nests (x = destroyed, solid dots = surviving, and open circles = renesting).

which were either at or just below the surface of the water. No eggs were found. The eleventh nest still was intact although water-borne debris filled the bowl and covered the eggs which, although still in the nest, were actually below the surface of the water. Prior to the storm, the eggs had been 5 inches above the water.

The cover.—In June 1954, three types of emergent cover, as well as upland and open-water areas existed in the Mud River Pool (Fig. 1).

An accumulation of "plant debris" occupied a former open-water area that had developed into a dense stand of soft-stem bulrush (*Scirpus validus*) intermixed with pure growths of sedges (*Carex pseudo-cyperus, C. lacustris,* and/or *C. atherodes*) during a drawdown of the pool in the summers of 1951 and 1952. This area developed an extremely dense marsh of these species when the pool was reflooded in the spring of 1953. Consequently there were many dead stems from the 1953 growth floating in the water when the 1954 growing season began. However, in 1954 the stands developed only a patchy new growth of light density, while the surface of the water was choked with dead stems and other debris from the previous year's growth. The dead stems were heavily utilized for nesting by coots, as illustrated by the concentration of nests shown in Fig. 1. These nests were quite exposed, and most were visible from the dike. All nests in this cover type were anchored to sparse clumps of living vegetation and thus had a very light overhead cover of new bulrush and/or cattail (*Typha latifolia*). The water depth throughout this cover type at the time of the storm averaged approximately 24–30 inches.

"Light cattail" occurred in deep-water areas bordering open water where cattail had become established on mud flats exposed by the drawdown. Such stands were usually composed of cattail plants with densities of approximately two stems per square foot and did not extend above the surface of the water more than 3 or 4 feet. Little debris remained from the growth of the previous season in such areas. Average water depths were about 30 inches.

Portions of the pool covered with "old cattail" were shallower areas occupied by cattail beds prior to and during the drawdown period. Water depths in such areas were about 12–18 inches at the time of the storm. The stands averaged about four

stems per square foot and most individual plants attained heights of 6 or more feet above the surface of the water. Some debris from the 1953 season remained in these stands which often were quite devoid of open-water channels. Most coot nests in this type were near edges of other vegetation types or open water.

Nest destruction in relation to open water and cover types.—An examination of the location of 12 nests along the edges of the large open-water area on the east end of the pool revealed the vulnerability of nests so situated. All but two of these were destroyed. Four of the ten destroyed nests were in light cattail (one at the edge of the small island of upland), and six were in plant debris. Two nests that were not destroyed were located on the lee side of the pool in plant debris. One other nest close to these two survived—this was 10 yards back from the edge and close to the dike.

The survival of 10 of 11 nests in the *old cattail* stands illustrated the protective value of this heavy cover. Few of these nests were actually adjacent to open water and thus not subject to severe wave action. The nests that were in areas of moderately heavy wave action survived the storm with the exception of a nest near the west end of the pool on the windward side of a rather small open-water area. This nest, which vanished, had been located in a small island of cattail which also was destroyed. Two nests in *light cattail* but well back from open water were not destroyed.

All 14 nests that were located in portions of the mat of *plant debris* and were not adjacent to open-water areas survived the storm. Without a doubt, the presence of large amounts of debris inhibited wave formation in the area and stopped the little wave action that was able to start in the adjacent borrow pit. This debris was thought to be the major factor in the survival of the 14 nests in this cover type.

Nest success and renesting.—The behavior of adult coots during the windstorm is unknown. The storm had little effect on hatching success of those nests that survived intact. Of the 29 that were known to have survived in Mud River Pool, 22 had either hatched or were hatching one week after the storm and the remaining seven were being incubated with no reduction in the number of eggs that had been present prior to the storm. Of the 29 nests, complete clutch-size data were obtained for 20. Three nests had 6 eggs, 5 each had 8 and 10 eggs, 4 had 9 eggs, 2 had 11 eggs, and 1 had 12 eggs. Average clutch size for the 20 was 8.9 eggs/nest.

Some coots apparently renested within a week after the storm. On June 15, six nests were found which showed every sign of having been just started. Five of these six were located in the vicinity of the large open-water area where heavy destruction had occurred. None of the six was thought to be under incubation, although they seemed to be loosely attended by adult birds. None was judged to contain partially hatched clutches, and the materials used in most of the nests showed recently plucked green vegetation. One each of the nests had one, three, four, and five eggs and two had two eggs each. The average clutch size of these six nests was less than three, while the average clutch size of nests being incubated was almost nine. Nests in this stage of development had not been observed in the pool since May 25.

Summary.—Eleven of 30 coot nests located prior to a windstorm of 90 mile-per-hour velocities were destroyed by wave action. Of 16 additional nests located after the storm, 10 had survived and six were apparent renestings. Nearly all nests to windward of large open-water areas were destroyed regardless of cover type. Hatching success of surviving nests apparently was unaffected. Data on 20 complete clutches indicated an average of 8.9 eggs per clutch.

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EDITORIAL NOTE

The editors wish to acknowledge the much-appreciated assistance rendered to the JOURNAL during the past year by the following: D. L. Allen, D. A. Arnold, J. R. Beer, A. J. Berger, G. K. Brakhage, E. L. Cheatum, R. S. Cook, C. Cottam, D. E. Davis, R. S. Dorney, J. T. Emlen, Jr., L. E. Foote, C. E. Friley, Jr., A. D. Geis, L. E. Givens, F. Greeley, D. R. Griffin, J. B. Hale, R. P. Hansen, H. C. Hanson, A. D. Hasler, R. L. Hine, Neil Hotchkiss, L. W. Krefting, J. P. Linduska, H. A. Mathiak, R. A. McCabe, H. S. Mosby, A. S. Mossman, J. C. Neess, P. H. Phillips, W. L. Robinette, V. Schultz, W. G. Sheldon, L. K. Sowls, J. G. Teer, D. R. Thompson, H. B. Tordoff, H. G. Uhlig, and W. L. Webb.

REVIEWS

Mammals of Northern Alaska / On the Arctic Slope. By James W. Bee and E. Raymond Hall. University of Kansas Museum of Natural History, Misc. Publication No. 8. 1956. 309pp. 5 plates, 1 colored. Paper $1.00, Cloth $4.00.

General handbooks covering all of North America, a book by Dufresne including the mammals of all of Alaska, and a number of short papers covering certain species or parts of Arctic Alaska have appeared from time to time, but this is the first work purporting to treat comprehensively the mammals of the northern slope of Alaska. With the present increased interest in the Arctic, and with the greatly increased volume of biological work being done in the Arctic today, this volume from the prolific workers at the University of Kansas has been awaited eagerly. Financial support for the project was supplied by the U.S. Navy's Office of Naval Research. Because the book is based on only two summers' field work in an area of 82,000 square miles, it is disappointing but not surprising to find it less complete and authoritative than the title suggests.

The book is composed of a 4-page Introduction, a 2-page Check-List of the Mammals of the Arctic Slope of Northern Alaska, accounts of the individual species or subspecies (248pp.), a Key to the Species of Mammals of the Arctic Slope of Northern Alaska (12pp.), and a final section of 23 pages covering Characteristics of the Mammalian Fauna, Geography and Climate, Northern Arctic Slope *versus* Southern Arctic Alpine Areas, Biotic Communities, Itinerary, and Acknowledgments. A 174-title section of Literature Cited concludes the volume.

The report covers the area from the crest of the Brooks Range north to and including the coastal waters of the Arctic Ocean. For each of the 41 species or subspecies (including *Lemmus trimucronatus subarcticus* new subspecies described here) known to occur in the area, the plan of treatment is the same: the scientific name, common name, an Eskimo name, a complete synonymy, a description, a list and map of records of occurrence, and a group of skull drawings; for all land mammals there is an additional section of Remarks, which varies in length from a short paragraph on the land otter to 42 pages for the brown lemming. Six additional mammals possibly occurring on the Arctic Slope are mentioned.

The book was evidently intended as a handbook of the mammals of the northern part of Alaska. In the reviewers' opinion, it could have been more accurately titled "Notes, Literature, and Opinions on the Mammals of Northern Alaska." The sections dealing with taxonomy and distribution represent for the most part a very thorough combing of the literature. Among the small mammals, especially the lemmings, voles, and shrews, the material included in the Remarks sections is new and adequate; these sections make up approximately half the book. Among the other species, the authors are evidently less at home, and the Remarks sections often reflect the information gleaned from what we judge to be a rather narrow circle of acquaintances.

A somewhat biased sampling among the errors noted reveals some peculiar omissions, some questionable interpretations, and a few inexcusable errors in fact. Among the questionable interpretations is the material on caribou migrations (pp. 242–250). It brings to mind the familiar story of the distorted impression of an elephant entertained by the blind man introduced to only a portion of the beast. Those of us familiar with the whole animal have a somewhat different view! So with caribou movements in northern Alaska. A century ago such a section synthesized from reports by the indigenes of the area would have been acceptable; today it is not. Far more detailed records of caribou movements and abundance are available from U.S. Fish and Wildlife Service files; the effort of obtaining the information would have been no greater than for some of the other hearsay reports so meticulously included.

Still concerning caribou, the reviewers were surprised to find the implication that caribou can be segregated by observation into 2-year-olds, 3-year-olds, cows, and adult bulls (p.243); our employees and co-workers find some of these distinctions difficult even with the caribou carcass at hand. The reviewers' opinions of the statements on predator-prey relationships are discussed in a review submitted to the *Journal of Mammalogy*. Suffice it to say here that one might well conclude that control of predation on caribou on the Arctic Slope of Alaska might well be achieved by elimination of boulders, ledges, and other prominences from which the wolves, wolverines, and bears pounce on the backs of their prey!

With regard to incompleteness, the sections on marine mammals are outstanding. For example, far more data are available on walrus than are included in the book; in fact, a study of walrus was conducted at Barrow while the authors were in the area, and at least part of the results were published as early as 1953.

As to errors in fact, the coyote is reputed to "have always been present as far as he (Sovalik) can remember" (p.168). The first record of the coyote in Alaska was about 1900, and its appearance in the Brooks Range and north is certainly far more recent. The other example concerns Dall sheep, which were considered to be well along in the rutting season at Chandler Lake on August 19 judged from fighting among males. Our data show that male sheep "fight," or at least butt horns, throughout

the year, and the rut occurs approximately three months later than Bee and Hall suggest.

On the other side of the ledger, there are many good points. We agree with the authors' views on proof of conspecificity (pp. 61–62); the tendency in many recent papers concerning Alaskan forms to synonymize gratuitously on the basis of speculation rather than specimens is regrettable.

The book is printed on a good grade of paper, is relatively free of typographical or other mechanical errors, and is well bound in either paper or cloth. The colored plate of shrews, voles, and lemmings done by R. P. Grossenheider is up to his usual standards. The ingenious use of graphs and charts has added much to the publication. The drawings of skulls are exceptionally well done, and clearly reproduced. The key to the mammals seems workable, and is certainly most welcome.

Lastly, wildlife biologists in Alaska could well take a lesson from the University of Kansas workers who completed their field work, squeezed their data for all it was worth, and promptly published their results. Our principal criticisms stem from the regrettably short period covered by their field work. —JOHN L. BUCKLEY AND ROBERT F. SCOTT, U.S. Fish and Wildlife Service, Box 998, College, and Box 280, Anchorage, Alaska.

Sea Fisheries: Their Investigation in the United Kingdom. Edited by Michael Graham. Edward Arnold, Ltd., London. 1956. xii + 487 pp., 12 plates, 115 figures. (List price $25.00 available at St. Martin's Press Inc., 103 Park Ave., New York 17, N.Y.)

This book embodies the principal scientific studies relating to the sea fisheries of the United Kingdom. In the preface Michael Graham states: "We have noted that, in the past half-century, general interest in marine and fishery science has greatly increased, and it is our intention that this book should be readable to anyone who is sufficiently interested, without special training in science or in fisheries."

The contributors and contents of the ten chapters of the book are: "Science and the British Fisheries," by Michael Graham; "Fisheries of the United Kingdom," by Henry Wood; "Plankton and Basic Production," and "Plankton and Fisheries Biology," by C. E. Lucas; "Benthos and the Shellfish of Commerce," by H. A. Cole; "The Pelagic Phase," by A. C. Simpson; "The Cod, Haddock and Hake," by B. B. Parrish; "Plaice," by Michael Graham; "The Theory of Fishing," by R. J. H. Beverton and S. J. Holt, and "Synopsis and Commentary," by Michael Graham. The book concludes with a bibliography and an index.

The first eight chapters of this book are informative and well written. Many references are given that should be of interest to American fishery biologists. In these chapters the reader is exposed in an easy manner to a vast amount of material and knowledge that has been accumulated concerning the sea fisheries of the United Kingdom.

Chapter IX, "The Theory of Fishing," is the climax of the book. The preceding eight chapters present the background and scientific information necessary to develop the theory of fishing. The main problem posed in the earlier chapters is: "How should a given fish population or community be exploited, and the amount and kind of fishing activity be adjusted, to obtain the best results?" Beverton and Holt use the available biological data and mathematics for developing population models to explain their theory. Later in their chapter a more complex theory is proposed in which they speculate beyond their present research. The chapter is concluded by this statement: "The lesson from it all is that in order to get the best possible results from the exploitation of these natural resources, man must be prepared to seek a full understanding not only of the characteristics of the fish populations as prey but of his own behaviour as predator."

I consider this the finest book dealing with the field of fishery science that I have ever read. Although it is concerned primarily with a foreign commercial marine fishery, I believe that American fresh-water fishery scientists will be inspired by the way Michael Graham and his associates have presented the field of fishery science. This book should certainly be of real help to teachers of graduate classes in fishery science.

The book is of fine quality, is well illustrated, and the format is good. By American standards, the price of the New York distributor is somewhat exorbitant. British dealers list this book at £5/5/– ($14.70).—WILLIAM C. STARRETT, Illinois Natural History Survey, Urbana, Illinois.

The Study of Plant Communities. By Henry V. Oosting. W. H. Freeman and Co., San Francisco. Second edition, 1956. viii + 440pp., illus. $6.00.

Dr. Oosting is Professor of Botany at Duke University. In 1948 he published *The Study of Plant Communities.* The second edition has now appeared. It differs very little from the first edition, except in the sections on plant succession, and in having an expanded citation list. Of the references, about one-third have appeared in the last ten years.

This volume is intended as an introduction to plant ecology at the upper-division university level. It emphasizes community structure in plant aggregations. It proceeds from a recognition of the existence of plant communities through methods of describing them in quantitative terms to the description of the various environmental factors that modify them. Then, from a discussion of plant succession, the author proceeds to the concept of the climax, the description and present distribution of climax regions of North America, and the shifting of climaxes with time.

In the final section, under "Practical Considerations," there is a treatment of Applied Ecology (forestry, range management, agriculture), Conservation (soil conservation, water supply, wildlife), Landscaping, Plant Indicators, and Human Ecology.

Space limitations have apparently forced the author to cover a great deal of ground lightly, so that the reader must often run down the references before he can fully understand a paragraph. For example, on page 43 we find, in a discussion of plotless sampling, "The Bitterlich variable-radius plotless method[171] assumes that the probability of a tree being included in a point count is proportional to its basal area. An angle-gauge is used to determine which trees are tallied . . . the method holds promise for ecological sampling[363]. . . ." It is apparent that a description of this degree of brevity is useful only if the reader has access to a library, where he may look up references 171 and 363 and discover for himself just what the technique entails. The frequency with which material is presented in this fashion makes the text of limited value to the off-campus reader.

For the university student, for whom the book is intended, the many (198) illustrations are of great value. It is unfortunate that the area in which a photograph was taken is not always stated, since the reader's comprehension is increased by geographical orientation. One might question, in a volume so compact, the inclusion of seven space-consuming pictures of common weather instruments. A number of the illustrations, especially in the sections dealing with environmental factors, are graphs or figures illustrating the relation between plants and their environment. These sometimes suffer from the same neglect evident in the case of the Bitterlich method—they are not explained or discussed, so that the reader, especially the inexperienced reader for whom the book is intended, must go to the original reference for enlightenment. This makes for slow progress.

Certain aspects of the place of animals in the biotic community are taken up, for example their role in pollination and dissemination. But there is little recognition of the effects that herbivores may have on community structure. On the contrary, one learns (p.221) that, "Deer and moose similarly have little effect on the plant communities where they browse, unless there is an overpopulation." In fact, however, especially in arid regions, even moderate populations of herbivores have demonstrable effects on community structure, because of their forage preferences.

The way in which animal associations change as plant succession advances is not mentioned here —a special disappointment in view of the author's extensive research in Piedmont successions.

The final section, in which "Practical Considerations" are taken up, is necessarily more superficial than the rest of the volume. Statements such as the following (p.385) are typical: "Our water supply is a natural resource just as are the others we have discussed. When its availability is reduced, it affects agriculture, industry, fish and game, recreation, and perhaps home use. The trend is already in the direction of its conservation. Probably it will go further." In future editions, one hopes that Dr. Oosting will leave exposition at this level to the elementary schools, and devote the space to an expansion of his previous sections.—R. D. TABER, Montana State University, Missoula, Mont.

Hunting the Lawless. By Hugh M. Worcester. American Wildlife Associates, Berkeley, California. 1955. 298pp. $5.00.

For several reasons Hugh Worcester's book is an important contribution to American wildlife literature. Protective laws and their enforcement are an essential aspect of wildlife management, but they have been neglected in our literature until recently. Worcester's is a fascinating and exciting personal account of the outstanding experiences in thirty years of game law enforcement work, chiefly as a federal Game Management Agent. Worcester took part in 25,000 law-violation cases, but he wisely describes only a few. This permits enough detail so that the methods used, the personalities involved, and the very real drama of these cases come alive.

Historically the book is important because it describes one type of wildlife management in the era before professional training was available in this country. Professional training in conservation law enforcement is only now becoming recognized as desirable, and Worcester's career developed in a time when wildlife professionals in virtually all fields were largely or entirely self-taught.

The magnitude of some of the violations described will surely be a surprise to many readers. In northern and central California during one period the author describes how 150 men were engaged in commercial duck hunting for five months of the year, and how two men sold $20,000's worth of waterfowl in one season. The author describes how this case actually demoralized the whole community, with the violators becoming heroes to many teen-agers in the area, and numbers of otherwise respectable citizens deliberately overlooking the offenses. The extent, however, to which he secured citizen cooperation in some of his more important cases is very gratifying.

The book is written in a very readable, quaint, and untutored style which I found very effective. The author's sincerity and conscientiousness stand out in every chapter, and his philosophy toward his work inspires respect. Unfortunately there are quite a number of misspellings and typographical errors, but certainly not enough to interfere seriously with the value of the book.

Among the accounts which will interest the wildlife student and conservationist are those describing the author's investigations of duck slaughters in

Mexico, bounty frauds, and depredation control. His descriptions of cooperation with state law-enforcement officials and of the objectives and activities under the Lacey Act and the migratory bird treaties are equally enlightening. One chapter describing experiences during 1931–34 as refuge manager at Tule Lake has some space devoted to botulism and lead poisoning as mortality factors. Here, and in the few other sections dealing with subjects other than law enforcement, the author's accuracy falters. He speaks of botulism as though it was an infectious disease; he attributes "lead poisoning" to the arsenic in the shot; and in the final chapter he waxes so enthusiastic over Ducks Unlimited that he flatly credits that organization with bringing the duck population from 30 million to 125 million and preserving duck shooting in this country ". . . as we have it today. . . ."

My criticisms, however, really apply only to those brief sallies into other aspects than the law-enforcement work which he knows so well and describes so effectively. Anyone contemplating a career in wildlife law enforcement will certainly enjoy and profit from this book, and laymen conservationists and wildlife management students generally will find it the best source of intimate knowledge of the problems in this field.—GUSTAV A. SWANSON, Department of Conservation, Cornell University.

The Rabbit. By Harry V. Thompson and Alastair N. Worden. New Naturalist Series. Collins, London. 1956. 240pp., illus. 16/–.

This new addition to an invaluable series of excellently edited books deals primarily with the common rabbit of central Europe, Britain, and Ireland, *Oryctolagus cuniculus cuniculus* Linn., with special reference to its status in Britain since the first appearance there of myxomatosis in the late summer of 1953.

Recent rabbit history in Britain threatens to follow much the same pattern as in Australia. Agricultural output has already taken so noticeable a jump that it is now government policy to employ all conceivable methods of eradication. England and France unfortunately both have an opposition school: In France there are 2,000,000 *chasseurs* whose primary interest is to hunt rabbits; in England there are hundreds of thousands of the less wealthy to whom the rabbit means cheap meat (often enough poached) and to whom coursing with whippets is still a national sport. These constitute a considerable element opposed to rabbit eradication.

The rest of the volume deals with every aspect of rabbit lore. Because nothing seems to have been overlooked, it is an unusually valuable reference book on the genus *Oryctolagus*. The type race, *O. c. cuniculus*, was apparently introduced into Britain and Ireland by the Normans, since there is no reference to rabbits in Domesday Book and the authors are able to trace the animal's gradual increase through the centuries. Its relatively slow spread is in contrast to its achievements in Australia and New Zealand where it met practically no opposition from the native fauna and little enough from man. In both these countries it has attained such numbers in locally favorable districts as to eliminate sheep raising as an industry by completely denuding the vegetation; it has also succeeded thereby, at least periodically and locally, in virtually eliminating itself. The species has been introduced successfully in Chile and on innumerable oceanic islands in both hemispheres; there is also a flourishing colony in the heart of Uganda.

Before the advent of myxomatosis, population densities in England and Wales frequently reached levels of 12,000 or more to the square mile; the record of over 25,000 came from the island of Skokholm off the Welsh coast. These densities make an interesting comparison with the highest populations of the snowshoe hare (*Lepus americanus*) probably ever recorded on the North American continent—20,000 to 30,000 to the square mile over limited areas in Alberta at the peak of the ten-year cycle.

The rabid, anti-predator game brethren of North America would do well to consider the authors' remarks on predation as they apply to rabbits in Britain and more especially Wales, where foxes and raptores are abundant and where rabbits nevertheless flourish. Their points are particularly telling, since the authors are not interested in defending predators and cannot be charged with bias.

Other chapters include physiology, reproduction, ecology, British methods of control and trapping, and rabbit legislation. All are up to date and treated with exemplary lucidity. As a reference book, *The Rabbit*, in spite of its comparative brevity, is probably without a peer. It is, moreover, eminently readable and excellently illustrated.—WM. ROWAN, Edmonton, Alberta.

Mammals of the Great Lakes Region. By W. H. Burt. University of Michigan Press, Ann Arbor. 1957. xv + 246 pp., 54 figs., 77 maps, 3 tables. $4.75.

This volume is mainly a revision of the author's *The Mammals of Michigan* (1946), enlarged to cover the entire Great Lakes region. Seventy-four endemic species are described. Subspecific identifications have been dropped and left for the "specialist." In the case of the difficult genus *Peromyscus*, an exception is made since *Peromyscus maniculatus bairdi* and *P. m. gracilis* have certain characters and habitats that would permit them to be treated as distinct species. The issue is clouded by recent work indicating that the two subspecies may intergrade. Only one change in nomenclature was noted, *Microtus ochrogaster* becoming *Pedomys ochrogaster*.

The key has been revised. Added to the excellent drawings are figures of the rostra of shrews and the enamel patterns of the upper cheek teeth of the voles. The enamel patterns of the molars of the microtines are very useful in identification. For student use, they are shown with greater clarity in Gunderson and Beer, *The Mammals of Minnesota* (1953).

The maps show approximately the range of the species in the Great Lakes region, and inserted in corners are drawings of the mammals under discussion and greatly reduced maps illustrating the range in North America. The latter are taken from the author's *A Field Guide to the Mammals* (1952). Leniency should be shown toward mapping the range of a species, since it is a difficult subject with which to cope. In but few cases are adequate data available for a state, and in the case of a mammal like the opossum the ink is scarcely dry on the map before revision is in order. In Wisconsin, e.g., the range of the fox squirrel, as mapped by Burt, should be extended to the northernmost tier of counties; and the red squirrel is absent south of the Wisconsin River except for the extreme southeastern counties.

The amount of condensed, essential information is impressive. Any student mastering the contents of the volume will be well grounded in mammalogy. —A. W. SCHORGER, Department of Forestry and Wildlife Management, University of Wisconsin.

Nature's Guardians. By Harry Edward Neal. Julian Messner, Inc., New York 18, New York. 1956. 192pp. $3.50.

Every professional conservationist receives many inquiries about the employment opportunities, the type of work, the salaries paid, and the kind of training required in various aspects of conservation work. He can now refer such inquiries from or on behalf of interested young people to this book, which is based on careful compiling of information from many different administrators in the federal conservation agencies. The young man of high school age who is considering conservation as a career will find here an excellent summary of the opportunities in the federal agencies. Virtually nothing is said about the career opportunities in the states.

The book should be available to every vocational guidance counselor in our high schools, and many a college professor advising freshmen will find it useful. The book serves its purpose well. With the exception of ignoring the career opportunities in state service, it seems well balanced and accurate. It contains an appendix with a well-selected list of references and sources of further information, which does list the state departments of game and fish or conservation. It is by far the best effort of its kind.—GUSTAV A. SWANSON, Department of Conservation, Cornell University.

American Water and Game Birds. By Austin L. Rand. E. P. Dutton & Co., Inc., New York. 1956. 239 pp., 167 photos. $11.50.

The book *American Water and Game Birds* belongs on the bookshelf of any individual who has enjoyed the esthetic value of this group of birds in their natural habitat. Written in a style that makes for easy reading, the book thoroughly covers the different species of water and game birds to be found in North America. Ample use of bird silhouettes and photographs, both color and black and white, tends to create and maintain the interest of the reader.

The book reveals the extensive field experience of Dr. Rand and his personal familiarity with this group of birds in North America. In a sense it is a "Duncan Hines" of notable concentration points of water and game birds in the United States and Canada. The volume is divided into 35 chapters that successively describe various families and species, with a general discussion on various aspects of the life history and behavior of each species.

The reviewer has only two personal objections to this publication, and these are of minor nature: (1) lack of references to other ornithological literature where the amateur might find more information; (2) the use of the term "Pochards" for the group of ducks that are commonly known as "Divers."

This publication will serve as an impetus for the layman and amateur bird watcher alike to enjoy more fully the magic of our American water and game birds.—E. L. KOZICKY, Olin Mathieson Chemical Corp., East Alton, Ill.

INDEX FOR VOLUME 21

Age ratios and age groups
deer, mule, 12
pheasant, ring-necked, 250
squirrel, gray, 339
Agee, C. P. The fall shuffle in central Missouri bob-whites, 329
Alfonso, P., *see* Emlen, J. T., Jr., 300
Allen, D. L. Fasanen og Vildtplejen (reviewed), 89
(Review of) The gray squirrel in West Virginia, 107
Allen, R. P.
honorable mention for work on flamingos, 363
Report on the whooping crane's northern breeding grounds (reviewed), 378
The flamingos, their life history and survival (reviewed), 106
Atkeson, T. Z., *see* Givens, L. S., 465

Baldpate, *Leucocytozoon* in, 100
Ball, R. C., *see* Waters, T. F., 385
Banfield, A. W. F. (Review of) The deer of North America, 105
Barnett, E. M., *see* Kirkpatrick, C. M., 341
Baskett, T. S., R. L. Dunkeson, and S. C. Martin. Responses of forage to timber stand improvement in the Missouri Ozarks, 121
Bass
largemouth
effect of, on small catfish, 27
reproduction in small ponds, 127
spawning, 130
survival, 129
yield, 183
rock
yield, 183
smallmouth
effect of assumed regulations, 187
feeding habits, 421
growth, 417
in warm-water ponds, 414
interspecific competition, 417
nesting study, 416
population dynamics, 418
yield, 183
Beaver
ecological effects, 80
pelt yields, British Columbia, 260
Bee, V. W. and E. R. Hall. Mammals of northern Alaska (reviewed), 474
Beer, J. R. (Review of) Successful trapping methods, 256
Belt, C. B. History of the committee on conservation of forests and wildlife of the Camp Fire Club of America, 1909–1956 (reviewed), 383
Bendell, J. F. and R. D. Lisk. *Dispharynx nasuta* in Hungarian partridge, 238
Bennett, G. W. and W. F. Childers. The smallmouth bass, *Micropterus dolomieui*, in warm-water ponds, 414
Bentley, A. A brief account of the deer in Australia, 221
Berryman, J. H. Our growing need: a place to produce and harvest wildlife, 319
Bizeau, E. G., *see* Steel, P. E., 38
Bluegill
effect of, on catfish fry, 27
reproduction in small ponds, 127
spawning, 130
survival, 129
Borell, A. E. (Review of) The future of arid lands, 254
Brinck, P., *see* Hanström, B., 384
Buckley, J. L. (Review of) Travels and traditions of waterfowl, 108
Buckley, J. L. and R. F. Scott. (Review of) Mammals of northern Alaska, 474
Burgess, G. D. Occurrence of *Leucocytozoon simondi* M. & L. in wild waterfowl in Saskatchewan and Manitoba, 99
Burroughs, R. D. (Review of) Wisconsin's renewable resources, 256
Burt, W. H. Mammals of the Great Lakes Region (reviewed), 477
Byrd, M. A., *see* Schultz, V., 315

Caldwell, L. D. Crop thickening and September nesting of doves, 247
Canvas-back
Leucocytozoon in, 100
resistance to trapping, 104
Capelin, eaten by fur seals, 237
Carlsen, J. C. and R. E. Farmes. Movements of white-tailed deer tagged in Minnesota, 397
Carney, S. M. and G. A. Petrides. Analysis of variation among participants in cock-crowing censuses, 392
Carp
effect of, on turbidity, 129
growth, 129
reproduction, 66, 127
spawning, 130
survival, 66, 129
tag recoveries, 280
vital statistics, 279
Carrying capacity, of uniform biotopes for mice, 114
Cat, house, as food of coyote, 426
Catfish, channel
mortality, 26
reproduction of, 22
stocking technique, 26
Chansler, W. S. Successful trapping methods (reviewed), 256
Chicken, prairie, interspecific dominance, 242
Childers, W. F., *see* Bennett, G. W., 414
Churchill, W. Conclusions from a ten-year creel census on a lake with no angling restrictions, 182

Clarke, C. H. D. (Review of) Der Waidgerechte Jäger, 111
Cod, eaten by seals, 241
Cole, L. S., *see* Taylor, G. N., 201
Cookingham, R. A., *see* Ripley, T. H., 459
Cooper, E. L., *see* Mraz, D., 66, 127
Coot
Leucocytozoon in, 100
nests destroyed by wind, 471
Cornell University, conservation education award to, 362
Corrinet, R. P., *see* Ripley, T. H., 459
Cougar, status in British Columbia, 260
Coulter, M. W.
Food of wood ducks in Maine, 235
Predation by snapping turtles upon aquatic birds in Maine marshes, 17
Coyote
effect of predation by, 432
food habits in Missouri, 424
pelt yields, British Columbia, 260
relation to rabbit population, 428
Cowan, A. B. and T. J. Peterle, *Leucocytozoon bonasae* Clarke in Michigan sharp-tailed grouse, 469
Cowan, I. McT., *see* Edwards, R. Y., 257
Crab, blue, effect of insecticide on, 44
Cragg, J. B. and N. W. Pirie. The numbers of man and animals (reviewed), 382
Craighead, F. C. and J. J., honorable mention for work on hawks, owls, and wildlife, 363
Crane, whooping, breeding-ground report (reviewed), 378
Crappie, black
reproduction in small ponds, 127
survival, 129
Creel census, lake with no angling restrictions, 182
Crippling losses, dove, mourning, 60
Crispens, C. G., Jr. Use of prolactin to induce broodiness in two wild turkeys, 462
Crockford, J. A., F. A. Hayes, J. H. Jenkins, and S. D. Feurt. Nicotine salicylate for capturing deer, 213
Cronan, J. M. Effects of predator guards on wood duck box usage, 468
Crow, eastern
attractant power of recorded calls, 91
predation on duck nests in hayfields, 196
recorded calls of, 91
repellent power of recorded calls, 91
Cycles
food explanation for, 230
microtine, causality of, 113
role of chance in, 293

Dahlberg, B. L. and R. C. Guettinger. The white-tailed deer in Wisconsin (reviewed), 255
Dalke, P. D., *see* Steel, P. E., 38
Darling, F. F. Pelican in the wilderness (reviewed), 253
Darrow, R. W. (review of) Birds and men, 381
Dasmann, R. F. (review of) The white-tailed deer in Wisconsin, 255
Davis, D. E. Manual for analysis of rodent populations (reviewed), 379
de Vos, Antoon. (review of) A field study of the timber wolf . . . on the Superior National Forest, 112
de Vos, Antoon and H. A. Merrill. Results of a woodchuck control experiment, 454
Deer, general
food of, in Australia, 224
forage response, relation to, 121
introduced in Australia, 221
nicotine salicylate in capture of, 213
overbrowsing effect in Northeast, 101
poisonous plants, 223
Deer, species
axis, history of, in Australia, 224
barasingha, history of, in Australia, 224
black-tailed
ovarian analysis, 62
review of book on, 105
fallow, history of, in Australia, 223
hog, history of, in Australia, 224
Japanese sika, history of, in Australia, 224
mule
agricultural relationships, 159
census techniques, 33
food, 159, 189
mortality by sex and age, 1
range use, 159
review of book on, 105
tooth development and wear, 134
red, history of, in Australia, 222
rusa, history of, in Australia, 223
sambar
history of, in Australia, 223
reproductive status of hunting kill, 225
white-tailed
as food of coyote, 426
captured with nicotine salicylate, 213
die-off in Louisiana, 245
effect of browsing by, 75
mortality due to malnutrition, 245
movements, Minnesota, 397
reviews of books on, 105, 255
sex ratio on poor range, 3
transect data analyzed, 274
Dorney, R. S. and V. H. Holzer. Spring aging methods for ruffed grouse cocks, 268
Dove, mourning
age groups, 170
crop thickening, 247
food of, in Illinois, 178
hunting study, Georgia, 58
migration, 179
mortality, 60
movements, 60
nesting in September, 247
soil fertility and body fat, 177
technique for sampling production, 226
weight and body fat, 169

Ducks, general
automatic nest trap for, 456
lead in tissues of, 97
mutilating accidents to, 458
trapping technique, gill net, 104
Ducks, species
black
prey of snapping turtles, 18
golden-eye
prey of snapping turtles, 18
ring-necked
prey of snapping turtles, 18
ruddy
Leucocytozoon in, 100
wood
attracted to oak mast, 465
food of, 235
predator guards on boxes for, 468
prey of snapping turtles, 18
see also canvas-back, etc.
Dunkeson, R. L., *see* Baskett, T. S., 121

Earthworms, nutrient composition of, 348
Ecological effects
alkalinity and productivity of lakes, 390
beaver, 80
fluorine on deer teeth, 149
soil fertility and body fat, doves, 177
Edgar, R. L. A device for holding rabbits during X-ray photography, 453
Edminster, F. C. (review of) Conserving American resources, 253
Edwards, R. Y. and C. D. Fowle. Harmony or discord? A critical look at wildlife management, 349
Edwards, R. Y. and I McT. Cowan. Fur production of the boreal forest region of British Columbia, 257
Elder, W. H. (review of) The numbers of man and animals, 382
Elk
age criteria, 435
food habits, 189
mandibular dentition, 435
Emlen, J. T., Jr., R. L. Hine, W. A. Fuller, and P. Alfonso. Dropping boards for population studies of small mammals, 300
Ensminger, A., *see* Glasgow, L. L., 245
Exotics, deer in Australia, 221

Fant, R. J. Criteria for aging pheasant embryos, 324
Fassett, N. C. A manual of aquatic plants (reviewed), 382
Feurt, S. D., *see* Crockford, J. A., 213
Fish, galvanotaxic responses of, 201
Fisher, pelt yields, British Columbia, 260
Fishing studies, bass, smallmouth, Illinois, 421
Flamingo, review of book on, 106
Food habits
coyote in Missouri, 424
deer, mule, 159, 189
duck, wood, 235
elk, 189
moose, 53
otter, sea, 241
seals, 237, 241
Fowle, C. D., *see* York, R. Y., 349
Fox
gray
as food of coyote, 426
red
pelt yields in British Columbia, 260
Frank, F. The causality of microtine cycles in Germany, 113
French, C. E., S. A. Liscinsky, and D. R. Miller. Nutrient composition of earthworms, 348
Frings, H. and M. Recorded calls of the eastern crow as attractants and repellents, 91
Frings, M., *see* Frings, H., 91
Fuller, W. A., *see* Emlen, J. T., Jr., 300
Funk, J. L., paper edited by, 22
Furbearers, production of, British Columbia, 257

Gaab, J. E., *see* Quimby, D. C., 435
Gadwall
Leucocytozoon in, 100
mutilating accident to, 458
Gashwiler, J. S., *see* Robinette, W. L., 134
Geis, A. D. Incidence and effect of warbles on southern Michigan cottontails, 94
Gilbert, P. F. and J. R. Grieb. Comparison of air and ground deer counts in Colorado, 33
Givens, L. S. and T. Z. Atkeson. The use of dewatered land in southeastern waterfowl management, 465
Glasgow, L. L. A woodcock sexing tool, 104
Glasgow, L. L. and A. Ensminger. A marsh deer "die-off" in Louisiana, 245
Glossary of wildlife terms, 373
Golley, F. B. An appraisal of ovarian analyses in determining reproductive performance of black-tailed deer, 62
Goose
Canada
clutch size, 40
cover types used by, 40
impacted gullets in, 96
helminths, 96
lead content in tissues of, 97
Leucocytozoon in, 100
mortality in, 96
nesting study, Idaho, 38
productivity, 38
Ross's
bulletin on, reviewed, 111
Graham, M. Sea fisheries: their investigation in the United Kingdom (reviewed), 475
Grebe, pied-billed, prey of snapping turtles, 18
Greenling, fringed, eaten by sea otters and seals, 241
Grieb, J. R., *see* Gilbert, P. F., 33

Grouse
ruffed
age criteria, spring cocks, 268
sharp-tailed
interspecific dominance in, 242
Leucocytozoon in, 469
Guettinger, R. C., *see* Dahlberg, B. L., 255
Gutermuth, C. R., awarded Leopold medal, 360

Hall, E. R., *see* Bee, J. W., 474
Hamerstrom, F. N., Jr. (review of) South African animal life, 384
Hansen, H. A., C. W. McNeil, and M. D. Priebe. Mortality of Canada geese with impacted gullets in eastern Washington, 1949–1954, 96
Hanson, H. C. and C. W. Kossack. Weight and body-fat relationships of mourning doves in Illinois, 169
Hanson, H. C., P. Queneau, and P. Scott. The geography, birds, and mammals of the Perry River system (reviewed), 111
Hanström, B., P. Brinck, and G. Rudebeck. South African animal life (reviewed), 384
Hare, varying
cycles of, 295
live trap for, described, 452
Harris, S. W. and W. H. Marshall. Some effects of a severe windstorm on coot nests, 471
Harry, G. B. Winter food habits of moose in Jackson Hole, Wyoming, 53
Hartley, H. O., *see* Jumber, J. F., 226
Haugen, A. O. Distinguishing juvenile from adult bobwhite quail, 29
Hayes, F. A., *see* Crockford, J. A., 213
Helm, W. T., *see* Neess, J. C., 279
Herring, absent in stomachs of fur seals, 238
Hickey, J. J.
editorial notes, 347, 473
(review of) The geography, birds, and mammals of the Perry River system, 111
(review of) History of the committee on conservation and wildlife of the Camp Fire Club of America, 383
Hine, R. L., *see* Emlen, J. T., Jr., 300
Hine, R. L. and K. G. Flakas. Stress response and survival time in three wildlife species, 239
Hochbaum, H. A.
Travels and traditions of waterfowl (reviewed), 108
terrestrial publication award to, 363
Hodgdon, K. W. Obituary of N. W. Fellows, Jr., 234
Holzer, F. V., *see* Dorney, R. S., 268
Hudoba, M., conservation education award to, 362
Hunting studies
dove, mourning, 58
effect on deer, in Australia, 225

Insecticides
effects of
BHC, 42
DDT, 42
Strobane, 42
effects on
birds, 51
crabs, 48
fish, 47
mammals, 51
Introductions, *see* Exotics

Jenkins, J. H., *see* Crockford, J. A., 213
Johnson, A. M., *see* Jumber, J. F., 226
Jones, D. A., *see* Robinette, W. L., 1, 134
Jumber, J. F., H. A. Hartley, E. L. Kozicky, and A. M. Johnson. Technique for sampling mourning dove production, 226

Kalmbach, E. R. (review of) A report on the whooping crane's northern breeding grounds, 378
Kenyon, K. W., *see* Wilke, F., 237
Kirkpatrick, C. M. and E. M. Barnett. Age criteria in male gray squirrels, 341
Korschgen, L. J. Food habits of the coyote in Missouri, 424
Kossack, C. W., *see* Hanson, H. C., 169
Kozicky, E. L.
(review of) American water and game birds, 478
see also Jumber, J. F., 226
Krefting, L. W., *see* Stoeckeler, J. H., 75
Krumholz, L. A., fisheries publication award to, 362

Labisky, R. F. Relation of hay harvesting to duck nesting under a refuge-permittee system, 194
Lance, sand, eaten by fur seals, 237
Larimore, R. W. A marginal-dot system of indexing reference cards, 92
Larsen, J. A. Wisconsin's renewable natural resources (reviewed), 256
Latham, R. M. A complete book of the wild turkey (reviewed), 109
Lauckhart, J. B. Animal cycles and food, 230
Lawrence, C. H. (review of) Wildlife law enforcement, 377
Lead, in tissues of waterfowl, 97
Leedy, D. L.
Minutes of the annual meeting, March 4, 1957, 359
Report of the Executive Secretary for the year 1956–57, 353
Report on the Wildlife Society council meeting, March 3, 1957, 357
Leitch, W. G. and R. A. McCabe. Avian recoveries from mutilating accidents to both legs, 458
Lensink, C. J.
Use of a gill net in trapping waterfowl, 103
Tomorrow's birthright (reviewed), 383
Leopold Award
previous recipients, 361
to C. R. Gutermuth, 360
Libby, W. L. A better snowshoe hare live trap, 452
Liscinsky, S. A., *see* French, C. E., 348
Lisk, R .D., *see* Bendell, J. F., 238
Low, J. B., *see* Robinette, W. L., 1

Lumsden, H. G. The problem of changing beliefs and attitudes, 463
Lyons, B. Tomorrow's birthright: a political and economic interpretation of our natural resources (reviewed), 383
Lynx, pelt yields, British Columbia, 260

MacLulich, D. A. The place of chance in population processes, 293
Mair, W .W. (review of) Pelican in the wilderness, 253
Mallard
attracted to oak mast, 465
Leucocytozoon in, 100
nesting study, 194
Management
angling restrictions, effect of, 182
artificial nests, catfish, 22
coal strip-mined lands, 402
critique of, 349
crops for dewatered areas, 466
dewatered land, 465
effect of assumed regulations, 187
electrical shocking in stream surveys, 201
employment needs, 364
employment requirements, 364
evaluation of wildlife plantings, Ohio, 405
green-timber reservoirs, 465
job standards in, 367
open dewatered areas, 466
planktonic response to lime application, 387
protection of duck nests in hay, 197
registered trap-lines, 257
salaries of biologists in, 376
soft-water lake, 385
students in, 365
terms, glossary of, 373
timber-stand improvement and forage response, 121
wildlife needs, production, and harvest, 319
wildlife, public-relation aspects of, 70
see also Techniques
Manville, R. H. The mammals of Shenandoah National Park (reviewed), 112
Marshall, W. H., *see* Harris, S. W., 471
Marten, pelt yields, British Columbia, 260
Martin, S. C., *see* Baskett, T. S., 121
Marzolf, R. C. Reproduction of channel catfish in Missouri ponds, 22
Massmann, W. H. and A. L. Pacheco. Shad catches and water temperatures in Virginia, 351
McCabe, R. A., *see* Leitch, W. G., 458
McDowell, R. D., *see* V. Schultz, 85
McNeil, C. W., *see* Hansen, H. A., 96
Merrill, H. A., *see* de Vos, A., 454
Mice
carrying capacity of uniform biotopes for, 114
condensation potential, 115
cycles, 113
food of coyote, 426
mortality, 117
reaction to dropping boards, 300
reproductive potential, 113
Miller, D. R., *see* French, C. E., 348
Mink, pelt yields, British Columbia, 260
Mole, as food of coyote, 426
Moose, food, 53
Morris, M. S. and J. E. Schwartz. Mule deer and elk food habits on the National Bison Range, 189
Mortality
age and sex, deer, 1
carp, 66, 286
catfish, channel, 26
deer
mule, 1
white-tailed, 245
dove, mourning, 60
microtines, 117
nutritional effects, deer, 2, 245
partridge
chukar, in stress experiment, 239
Hungarian, in stress experiment, 239
pheasant embryos, 325
postnatal, deer, 6
prenatal, deer, 1
rabbit, cottontail, in stress experiment, 239
winter, deer, 9
see also Predation
Movement
bobwhite, fall, 329
deer, white-tailed, Minnesota, 397
dove, mourning, 60
fish, marked, 285
Moyle, J. B. (review of) A manual of aquatic plants, 382
Mraz, D. and E. L. Cooper.
Natural reproduction and survival of carp in small ponds, 66
Reproduction of carp, largemouth bass, bluegills, and black crappies in small rearing ponds, 127
Muncy, R. J., *see* Schultz, V., 274
Muskellunge, yield, 183
Muskrat
pelt yields, British Columbia, 260
prey of
coyote, 429
snapping turtle, 19

Neal, H. E. Nature's guardians (reviewed), 478
Neess, J. C., W. T. Helm, and C. W. Threinen. Some vital statistics in a heavily exploited population of carp, 279
Neff, D. J. Ecological effects of beaver habitat abandonment in the Colorado Rockies, 80
Nelson, D. J. Some aspects of dove hunting in Georgia, 58
Nesting studies
bass, smallmouth, 416
catfish, channel, 22
coot, 471
goose, Canada, 38
mallard, 194
teal, blue-winged, 194

Nutrition
earthworm constituents, 348
influence on deer mortality, 2
and tooth eruption, deer, 150

Obituary of
Fellows, Nathan Warren, Jr., 234
Oosting, H. V. The study of plant communities (reviewed), 475
Opossum
depredation by, 90
as food of coyote, 426
predation on duck nests, 198
Otter
river
pelt yield, British Columbia, 260
sea
food of, 241

Pacheco, A. L., *see* Massmann, W. H., 351
Parasites
blood parasites in waterfowl, 100
Cuterebra horripilum on cottontails, 94
Dispharynx nasuta in Hungarian partridge, 238
helminths in Canada geese, 96
Leucocytozoon bonasae in sharp-tailed grouse, 469
Leucocytozoon simondi in waterfowl, 99
warbles, incidence and effect, cottontails, 94
Parson, R. L. Conserving American resources (reviewed), 253
Partridge
chukar
response in stress experiment, 239
Hungarian
Dispharynx nasuta in, 238
response in stress experiment, 239
Perch, yellow
age distribution, stunted population, 389
growth following lime application, 389
yield, 183
Peterle, T. J., *see* Cowan, A. B., 469
Pheasant, ring-necked
age criteria
embryos, 324
spur length, 248
age ratios, 250
flush device tested, 461
interspecific dominance in, 242
killed by hay mower, 461
mutilating accidents, 458
spur growth, 249
Pintail, *Leucocytozoon* in, 100
Pirie, N. W., *see* Cragg, J. B., 382
Pollack, Alaska, eaten by seals, 237, 241
Predation
by coyote, evaluated, 432
on duck nests in hayfields, 196
predator guards on wood duck boxes, 468
by turtle, snapping, 17
see also Mortality
Priebe, M. D., *see* Hansen, H. A., 96

Production and recruitment
bass, largemouth, in small ponds, 130
bluegill in small ponds, 130
carp in small ponds, 66
carp, 130, 289
catfish, channel, 22
crappie, black, in small ponds, 130
doves, mourning, technique for sampling, 228
goose, Canada, 38
population density, effect of, 66
young trees in hardwood-hemlock forest, 75
Progulske, D. R. A collar for identification of big game, 251
Public relations and wildlife management, 70

Quail, bobwhite
age criteria, 29
fall shuffle, 329
as food of coyote, 426
index to wintering populations, 153
size of managed areas, 334
summer whistling cock count, 153
use of black locust, 459
Queneau, P., *see* Hanson, H. C., 111
Quimby, D. C. and J. E. Gaab. Mandibular dentition as an age indicator in Rocky Mountain elk, 435

Rabbits, general
holding device during X-ray photography, 453
Rabbits, species
cottontail
flushing-line data, 317
as food of coyote, 426
killed by hay mower, 461
litter size, 90
population data, 315
propagation in pens, 90
response in stress experiment, 239
warbles, effect of, 94
European
book on, reviewed, 477
jack
as food of coyote, 426
reproduction of, in droughts, 244
snowshoe, see Hare, varying
Raccoon
as food of coyote, 426
predation on duck nests, 198
status in British Columbia, 260
Rails, prey of snapping turtles, 18
Rand, A. L., American water and game birds (reviewed), 478
Rats, as food of coyote, 426
Recruitment, *see* Production and recruitment
Redhead
broods in Wisconsin, 194
Leucocytozoon in, 100
Repellents
recorded calls, crow, 91
Riley, C. V. Reclamation of coal strip-mined lands with reference to wildlife plantings, 402

Ripley, T. H., R. A. Cookingham, and R. P. Corrinet. Black locust for quail in Massachusetts, 459
Robinette, W. L., J. S. Gashwiler, J. B. Low, and D. A. Jones. Differential mortality by sex and age among mule deer, 1
Robinette, W. L., D. A. Jones, G. Rogers, and J. S. Gashwiler. Notes on tooth development and wear for Rocky Mountain mule deer, 134
Rogers, G., *see* Robinette, W. L., 134
Rosene, W., Jr. A summer whistling cock count of bobwhite quail as an index to wintering populations, 153
Ross, H. H. (review of) The aquatic insects of California, 110
Rowan, Wm. (review of) The rabbit, 477
Rudebeck, G., *see* Hanström, B., 384
Russo, J. P. The desert bighorn sheep in Arizona (reviewed), 380

Salmon, eaten by fur seals, 237
Scaup, lesser
  Leucocytozoon in, 100
Schoenfeld, C. A. Public relations aspects of wildlife management, 70
Schorger, A. W. (review of) Mammals of the Great Lakes Region, 477
Schroeder, C. H. A calculator for handling large series of age-brood data, 459
Schultz, V. and M. A. Byrd. An analysis of covariance of cottontail rabbit population data, 315
Schultz, V. and R. D. McDowell. Some comments on a wild turkey brood study, 85
Schultz, V. and R. J. Muncy. An analysis of variance applicable to transect population data, 274
Schulze, H. Der Waidgerechte Jäger (reviewed), 111
Schwartz, J. E., *see* Morris, M. S. 189
Scoters, trapped in gill net, 104
Scott, Peter, *see* Hanson, H. C., 111
Scott, R. F., *see* Buckley, J. L., 474
Seal
  fur, food of 237
  harbor, food of, 241
Sex ratios
  deer
    mule, 1
    white-tailed, 3
  editorial note on, 347
  factors controlling, 2
  fetal, 1
  squirrel, gray, 339
Shad, effect of water temperatures on catch, 351
Sharp, W. M. Social and range dominance in gallinaceous birds, 242
Sheep, desert bighorn, bulletin on, reviewed, 380
Sheffer, D. A.
  Cottontail rabbit propagation in small breeding pens, 90
  correction re least weasel, 385
Shoveller, *Leucocytozoon*, in, 100
Shrews
  food of coyote, 426
  reaction to dropping boards, 305
Sigler, W. F.
  Wildlife law enforcement (reviewed), 377
  see also Taylor, G. N., 201
Skunk
  spotted
    as food of coyote, 426
  striped
    as food of coyote, 426
    predation on duck nests, 198
    status in British Columbia, 260
Smith, D. R. (review of) The desert bighorn sheep in Arizona, 380
Squirrel
  fox
    as food of coyote, 426
  gray
    age criteria, 339
    as food of coyote, 426
    mortality, 335
    population fluctuations, 335
    review of bulletin on, 107
    sex ratios, 339
    skeletal measurements, 343
  ground
    as food of coyote, 426
  red
    pelt yields, British Columbia, 260
Starrett, W. C. (review of) Sea fisheries: their investigation in the United Kingdom, 475
Steel, P. E., P. D. Dalke, and E. G. Bizeau. Canada goose production at Gray's Lake, Idaho, 1949–1951, 38
Stenlund, M. H. A field study of the timber wolf (reviewed), 112
Stickel, W. H. (review of) The mammals of Shenandoah National Park, 112
Stoeckeler, J. H., R. O. Strothmann, and L. W. Krefting. Effect of deer browsing on reproduction in the northern hardwood–hemlock type in northeastern Wisconsin, 75
Stokes, A. W.
  (review of) The flamingos: their life history and survival, 106
  Validity of spur length as an age criterion in pheasants, 248
Strothmann, R. O., *see* Stoeckeler, J. H., 75
Sunfish, redear, in spawning ponds of catfish, 27
Survival
  smallmouth bass in warm-water ponds, 415
  see also Mortality
Swanson, G. A. (Reviews of) Fasanen og Vildtplejen, 89; Hunting the lawless, 476; Nature's guardians, 478

Taber, R. D. (review of) The study of plant communities, 475
Taylor, G. N., L. S. Cole, and W. F. Sigler. Galvanotaxic response of fish to pulsating direct current, 201
Taylor, W. P. The deer of North America (reviewed), 105

Teal
  blue-winged
    Leucocytozoon in, 100
    nesting study, 194
    prey of snapping turtles, 18
  green-winged
    Leucocytozoon in, 100
Techniques
  age criteria
    bobwhite, 29
    deer, mule, 134
    elk, 435
    grouse, ruffed, 268
    pheasant embryos, 324
    squirrels, gray, 341
  analysis of covariance, rabbit data, 315
  analysis of rodent populations (reviewed), 379
  analysis of variance, transect data, 268
  artificial nesting sites, catfish, 23
  automatic nest trap, waterfowl, 456
  calculator for aged-brood data, 459
  capturing deer with nicotine salicylate, 213
  census
    aerial counts, deer, 33
    ground counts, deer, 33
  to change beliefs and attitudes, 463
  collar for identification, big game, 251
  dropping-board population index, 300
  flush devices tested, 461
  green-timber reservoirs for waterfowl, 465
  holding rabbit during X-ray photography, 453
  identification of big-game, 251
  indexing reference cards, 92
  live trap for snowshoe hare, 452
  marking fish, 280
  ovarian analysis, 62
  pheasant cock-crowing census, variables in, 392
  reclamation of strip-mined land, 402
  sampling mourning dove production, 226
  sexing tool for woodcock, 104
  stocking catfish, 26
  trapping ducks with gill net, 103
  trapping methods, review of, 256
Tevis, Lloyd, Jr. (Review of) Manual of analysis of rodent populations, 379
Thompson, H. V. and A. N. Worden. The rabbit (reviewed), 477
Transplantation, *see* Introductions
Threinen, C. W., *see* Neess, J. C., 279
Trout, rainbow, galvanotaxic responses, 202
Turkey, wild
  brood study, 85
  broodiness induced by prolactin, 462
  review of book on, 109
Turtle, snapping, predation by, 17

Uhlig, H. G.
  The gray squirrel in West Virginia (reviewed), 107
  Gray squirrel populations in extensive forested areas of West Virginia, 335
Usinger, R. L. Aquatic insects of California (reviewed), 110

Walker, E. A. (review of) A complete book of the wild turkey, 109
Walleye, yellow
  effect of assumed regulations, 187
  yield, 183
Waterfowl
  automatic nest-trap for, 456
  review of book on, 108
Waters, T. F. and R. C. Ball. Lime application to a soft-water unproductive lake, 385
Weasel, least
  correction regarding, 384
  depredation by, 90
Weasel, pelt yields, British Columbia, 260
Webb, W. L. Interpretation of overbrowsing in northeastern forests, 101
Welker, R. H. Birds and men (reviewed), 381
Weller, M. W. An automatic nest-trap for waterfowl, 456
White, G. F. The future of arid lands (reviewed), 254
Whiting, eaten by fur seals, 237
Wildlife Society
  annual meeting, minutes of, 359
  budget, 358
  bylaws, 368
  committee reports, 360, 373
  committees 1957–58, ii
  council meeting, minutes of, 357
  Executive Secretary's report, 353
  financial report, 355
  Leopold Award, 360
  membership list, v
  nominations for officers, 1958–59, 451
  officers 1957–58, ii
Wilke, F. Food of sea otters and harbor seals at Amchitka Island, 241
Wilke, F. and K. W. Kenyon. Food of fur seals in the eastern Bering Sea, 237
Wilkins, B. T. Range use, food habits, and agricultural relationships of the mule deer, Bridger Mountains, Montana, 159
Wolf
  bulletin on, reviewed, 111
  pelt yields, British Columbia, 260
Wolverine, pelt yields, British Columbia, 260
Woodchuck
  control experiment, 454
  as food of coyote, 426
Woodcock
  sexing tool for, 104
  use of black locust stands, 459
Worcester, H. M. Hunting the lawless (reviewed), 476
Worden, A. N., *see* Thompson, H. V., 477

Zorb, G. L. Effectiveness of two flushing devices used in hay mowing, 461